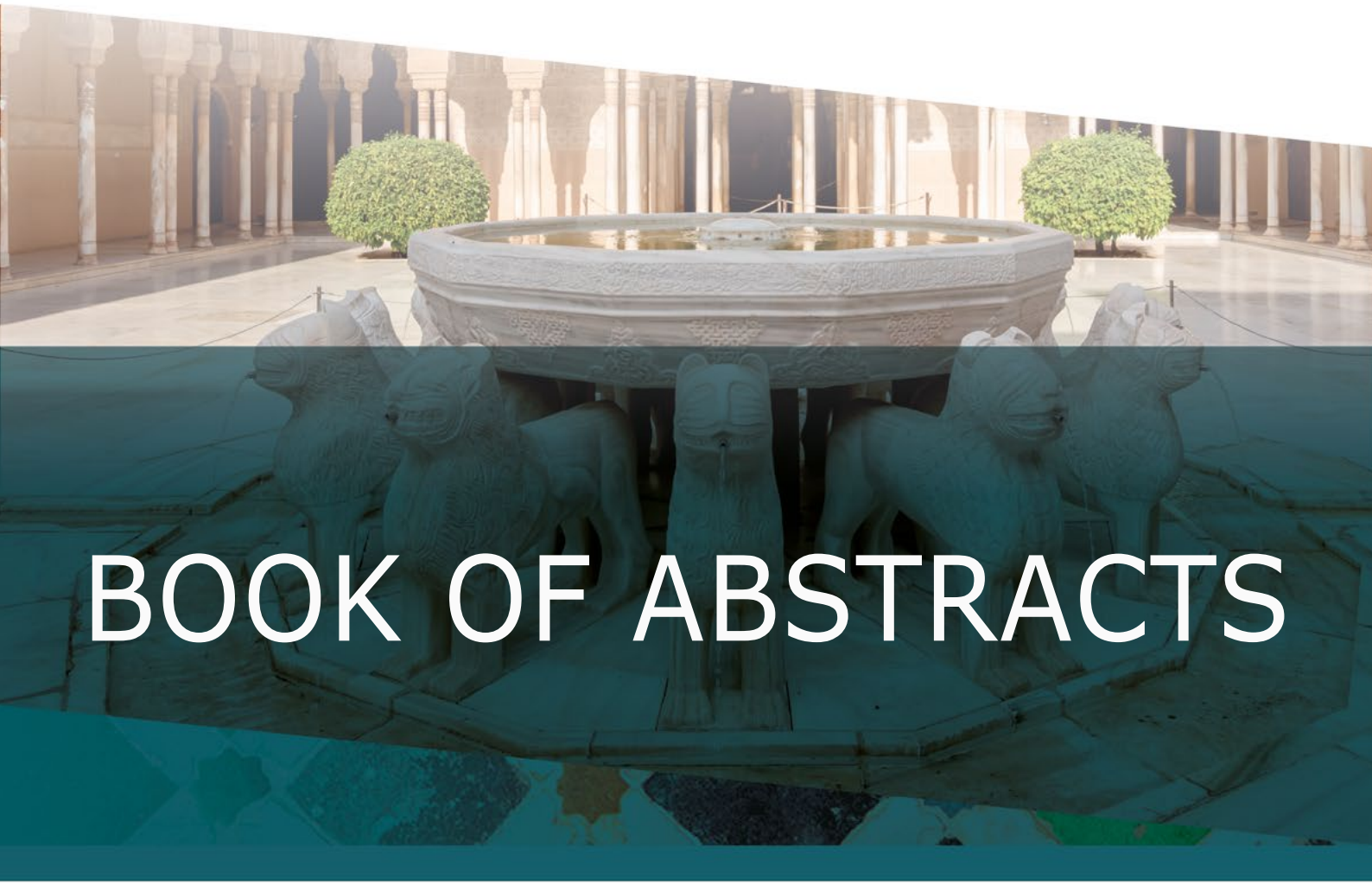
UNIVERSIDAD DE GRANADA

20TH FOOD COLLOIDS CONFERENCE

Granada, 22 - 26 March 2026
University of Granada



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2026

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GREETINGS

Granada, 22nd to 26th March

Dear Colleagues,

On behalf of the local organizing committee, it is both an honor and a pleasure to invite scientists from around the world to the 20th Food Colloids Conference, taking place in Granada, Spain, from March 22nd–27th, 2026.

This conference serves as a global platform for experts from academia and industry to share their latest research and insights into the fascinating and complex world of food colloids. The 20th edition will highlight the latest trends in colloidal food systems while continuing to explore the timeless principles of physical chemistry in the field. A key focus this year will be on sustainable food colloids such as insects, plant and microbial-based approaches, including their multiscale characterization and applicability in food delivery systems. Additionally, the conference will broaden its scope to include AI methods and digital technologies in food colloids fostering interdisciplinarity in food research. .

The Food Colloids Conference has a rich history, dating back to its inception in Leeds in 1986. Since then, it has continued to unite scientists from diverse disciplines, all dedicated to advancing the physical chemistry of colloidal food systems. This 20th edition aims to analyse the state of the art in food colloids, commemorate the achievements and look into the challenges facing the future generation of foods.

We are delighted to host the conference in Granada, the city of Alhambra and tapas. The University of Granada, with a history spanning nearly 500 years, will welcome participants to its Faculty of Sciences, conveniently located within walking distance of the city center.

On behalf of both the organizing committee and the international steering committee, we eagerly anticipate welcoming you to Granada in March 2026 for an inspiring and productive exchange in food colloid science!

We look forward to seeing you there.

Warm regards,
Prof. Julia Maldonado-Valderrama
Faculty of Sciences
University of Granada

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SCIENTIFIC PROGRAM

	Sunday 22nd			
18:00h-21:00h	Welcome Reception / Carmen de la Victoria Registration			
	Monday 23rd	**Tuesday 24th**	**Wednesday 25th**	**Thursday 26th**
08:00h-08:30h	Registration			
08:30h-09:00h	WELCOME AND OPENING	Registration		
	TOPIC: Emulsions, foams and gels	TOPIC: Alternative, plant-based, clean-label, sustainable food colloids	TOPIC: Multiscale characterisation and novel structures	TOPIC: Encapsulation, delivery, bioaccessibility and nutrition
	CHAIR: Eleni Kalogianni	**CHAIR**: Martin Leser	**CHAIR**: Miguel Cabrerizo Vílchez	**CHAIR**: Ulrike van der Schaaf
09:00h-09:50h	PLENARY LECTURE PL1 – Charlotte Jacobsen (Technical University of Denmark, Denmark) Prediction and validation of emulsifying properties of peptides in oil-in-water emulsions	PLENARY LECTURE PL2 – Anna Ström (Chalmers University of Technology, Sweden) Functional and health aspects of plant protein – polysaccharides interactions	PLENARY LECTURE PL3 – Marta Martínez Sanz (CIAL, UAM-CSIC, Spain) From structure to nutrition: Linking the multi-scale architecture of alternative food systems to their digestion mechanisms	PLENARY LECTURE PL4 – Ben Boyd (Monash University, Australia & University of Copenhagen, Denmark) A new look at milk as a drug delivery system, through the lens of lipid digestion
	CHAIR: Charlotte Jacobsen	**CHAIR**: Anna Ström	**CHAIR**: Marta Martinez Sanz	**CHAIR**: Ulrike van der Schaaf
09:50h-10:05h	O1 – Jolijn Koomen (INRAE, France) – Linking colloidal structure to antioxidant function in legume protein-stabilised emulsions	O17 – Gireeshkumar Balakrishnan (Le Mans Université, France) – Carrageenan Gels Formed Through Crosslinking with Rapeseed Proteins: Role of Electrostatic and Hydrogen- Bonding Interactions	O33 – Theresia Heiden-Hecht (Jülich Centre for Neutron Science, Germany) – Phospholipids disrupt the interfacial network of proteins at the oil/water interface	O48 – Ilona E. Kłosowska-Chomiczewska (Gdańsk University of Technology, Poland) – Dynamic colloidal transformations of human milk during infant in vitro digestion
10:05h-10:20h	O2 – Gradzielski Michael (Technische Universität Berlin, Germany) – Food-Grade Nanoemulsions Formed with Triacylglycerols and Different Biosurfactants as Stabilisers	O18 – Nicola Cesario Angelino (Aarhus University, Denmark) – Structuring starch–protein systems from pea dry fractionation side streams for sustainable food applications	O34 – Kerstin Risse (Technische Universität Berlin, Germany) – Structure, Heat, and Time: The Dynamic Life of Protein–Phospholipid Oil–Water Interfaces	O49 – Sébastien Marze (INRAE, France) – In vitro digestion of dairy milk and cream, and of their vegetal analogs
10:20h-10:35h	O3 – Gökhan Uğur Atı (Aarhus University, Denmark) – Association of endogenous phospholipids with pea globulins: effect on their structure and functionality	O19 – Emanuele Greco (University of Parma, Italy) – Blend or not to blend? Functional and Colloidal Properties of Yeast–Pea Protein Mixtures	O35 – Jasper Landman (Wageningen University and Research, the Netherlands) – Dynamics of pulse protein arrested states – an in situ GISAXS study	O50 – Maria de las Nieves Siles-Sanchez (Aarhus University, Denmark) – Monitoring iron speciation during gastrointestinal digestion: X-ray Absorption Spectroscopy
10:35h-10:50h	O4 – Supratim Ghosh (University of Saskatchewan, Canada) – Influence of phospholipids and a novel vegetable oil blend on the formation and quality of faba protein-stabilized plant-based whipped cream	O20 – Rose GAZEAU (Université de Bordeaux & ITERG, France) – Faba Bean as a Promising Emulsifying and Gelling Alternative to Soy	O36 – Olaf Holderer (Jülich Centre for Neutron Science, Germany) – Sustainable emulsions stabilized by cruciferin that forms dynamic interfacial architectures	O51 – Eleni P. Kalogianni (International Hellenic University, Greece) – Towards the development of food delivery systems by making use of microgel stabilized emulsions

* Lunch and coffee are served in posters area

	Monday 23rd	Tuesday 24th	Wednesday 25th	Thursday 26th
10:50h-11:20h	COFFEE BREAK			
				TOPIC: AI methods and digital technologies in food colloids
	CHAIR: Reinhard Miller	**CHAIR**: Björn Bergenståhl	**CHAIR**: Taco Nicolai	**CHAIR**: Pedro García Moreno
11:20h-11:50h	KEYNOTE K1 – Karin Schroen (Wageningen University and Research, the Netherlands) – Monitoring dynamic processes in food using microfluidics	KEYNOTE K3 – Ben Kew (University of Leeds, UK) – Delubrication by plant proteins: Understanding and addressing using colloidal technologies	KEYNOTE K5 – Marta Krasowska (Adelaide University, Australia) – Emulsifier Saturation Modulates Interfacial Monoglyceride Crystallisation and Polymorphic Transitions	KEYNOTE K7 – Tim J Wooster (Nestlé Research, Switzerland) – Hyperspectral Imaging: "Night Vision" that unlocks emulsion stability monitoring in complex systems
	CHAIR: Karin Schroen	**CHAIR**: Rocío Morales Medina	**CHAIR**: Marta Krasowska	**CHAIR**: Pedro García Moreno
11:50h-12:05h	O5 – Fathinah Islami Hasyyati (Wageningen University and Research, the Netherlands) – Coalescence in Pickering emulsions: influence of deacetylation of chitin nanoparticles and dispersed phase fraction investigated by microfluidic techniques	O21 – Francisco Vilaplana (KTH Royal Institute of Technology, Sweeden) – Enzymatic engineering of plant-based dietary fibre hydrogels from agricultural side streams	O37 – Niklas Lorén (RISE Research Institutes, Sweeden) – The influence of wax-based oleogelators on microstructure evolution, rheology and diffusion	O52 – Simha Sridharan (University of Leeds, UK) – Fingerprinting Protein Adsorption Classes to Identify 'Ideal' Plant Protein-Based Emulsifiers
12:05h-12:20h	O6 – Lovikka Ville A. (University of Helsinki, Finland) – Atomic force microscopy of undried Pickering emulsions at the nm and µm scale	O22 – Thidarat Makmoon (University of Birmingham, UK) – Formulation engineering of melt-in-the-mouth plant-based protein-rich gels	O38 – Dieke Groot Nibbelink (Wageningen University and Research, the Netherlands) – Oleogelation using dried protein particles	O53 – Gopesh Patel (University of Saskatchewan, Canada) – Predicting random jamming-induced repulsive gelation in sodium caseinate-stabilized polydisperse nanoemulsions by combining the entropic, electrostatic, interfacial and steric interactions
12:20h-12:35h	O7 – Gijs D. Konings (Wageningen University and Research, the Netherlands) – Tuning the Mechanical Properties of Emulsions with Adhesive Protein Nanoparticles	O23 – Ulrike van der Schaaf (Karlsruhe Institute of Technology, Germany) – Polysaccharide-based microgels serve as fat replacers in fermented dairy products	O39 – Carsten Nachtigall (Technische Universität Dresden, Germany) – Structural modification of microbial exopolysaccharides and its impact on their functionality	O54 – Giovanni Tizzanini (Chalmers University of Technology, Sweeden) – Predicting in vitro digestion of gelatin gels from videos using machine and representation learning
12:35h-12:50h	O8 – Qimeng Wang (Wageningen University and Research, the Netherlands & China Agricultural University, China) – Microbubble powders using freeze-dried Pickering emulsions	O24 – Cordelia Selomulya (UNSW Sydney, Australia) – Structuring Plant-Based Foods with Double-Network Emulsion Gels	O40 – Gleb Yakubov (University of Leeds, UK) – Multiscale Characterization of Interfacial Binding Between Soluble Amylose Chains and Waxy Corn Starch Granules	O55 – Jeta Purrini (Wageningen University and Research, the Netherlands) – Which molecular parameters predict foaming properties – A soft matter approach
	CHAIR: Francisco Galisteo González	**CHAIR**: Francisco Javier Espejo Carpio	**CHAIR**: Raúl Pérez Gálvez	

* Lunch and coffee are served in posters area

	Monday 23rd	Tuesday 24th	Wednesday 25th	Thursday 26th
12:50h-13:20h	F1 – Andrea Moreno Revuelta (University of Granada) – From olive waste to bioactive colloids: valorization of maslinic acid through solid lipid nanoparticles. F2 – Cyprien Bouju (INRAE) – Thermodynamic Incompatibility and Phase Inversion in Emulsions Stabilized by Uncracked Vegetal Byproducts. F3 – Vilena Petrova-Thuy (Delft University of Technology) – Rescaling of flow curves for food emulsions. F4 – Simon Müller (ETH Zürich) – In situ gas foaming of plant-based dispersions into porous food structures. F5 – Umay Vardar (University of Saskatchewan) – Oleosomes (natural lipid droplets) as building blocks for structured emulsion gels. F6 – Tiago C. Pinto (University of Helsinki) – Spray-chilled oleogel particles enabling hierarchical oleogel-in-oleogel structures.	F11 – Sarah Verkempinck (KU Leuven) – Extraction and processing shape the structural and emulsifying properties of pea proteins. F12 – Toya Ishii (University of Leeds, UK & Kagawa University, Japan) – In operando-SAXS analysis of multiscale structural changes in food dispersions during in vitro digestion processes. F13 – Nana Li (Wageningen University) – Bridging Lubrication and Sensory Perception in Plant-based Beverages. F14 – Stefano Parenti (BOKU University) – Arabinoxylan-protein complexes as new structuring ingredients for meat replacers: effect of enzymatic treatments on gel structure. F15 – Yi Li (University of Leeds) – Electrospinning of hybrid lipid-polymer fibres for cultured meat applications. F16 – Fangxin Lyu (Technische Universität Berlin) – Synergistic heat-induced gelation of mixtures from pulse and rapeseed protein: impact of pulse source.	F23 – Mengyue Xu (Wageningen University) – Designing and Understanding Thermoresponsive Shape-Shifting in 4D-Printed Pea-Based Foods and its Applications. F24 – Arno Wouters (KU Leuven) – Heat-induced aggregation of faba bean proteins: influence of heating temperature and protein concentration on induced molecular interactions. F25 – Scheermeijer Roos (Wageningen University) – Protein aggregate oleogels: effect of aggregate properties on oleogel texture.. F26 – Sukirti Joshi (University of Southern Denmark) – Deciphering Acidulant-Mediated Gelation of Hybrid Systems through Advanced Imaging and Rheology. F27 – Cristina Prieto (Institute of Agrochemistry and Food Technology, IATA) – Recent Developments in Electrospraying Assisted by Pressurized Gas for the Encapsulation of Challenging Bioactives. F28 – Johannes Marburger (Karlsruhe Institute of Technology) – Encapsulation of emulsions in monodisperse alginate capsules: a high-throughput droplet millifluidics approach.	AWARDS AND CLOSING
13:20h-14:30h	**LUNCH**			
	CHAIR: Miguel Angel Fernandez Rodriguez	**CHAIR**: Milena Corredig	**CHAIR**: Elke Scholten	
14:30h-15:00h	KEYNOTE K2 – Patricia Lopez-Sanchez (Institute of Marine Research IIM-CSIC, Spain) – Hydrogel Model Systems to Decode Polysaccharide Interactions and Rheology in Seaweeds	KEYNOTE K4 – Yifan Zhang (Wageningen University and Research, the Netherlands) – The role of serum properties in juiciness perception of plant-based meat analogues	KEYNOTE K6 – Bettina Wolf (University of Birmingham, UK) – Impact of functional properties and thermo-mechanical pre-treatment on freeze structured fibrous pea protein isolate textures	

* Lunch and coffee are served in posters area

	Monday 23rd	Tuesday 24th	Wednesday 25th	Thursday 26th
	CHAIR: Carla di Mattia	**CHAIR**: Federico Casanova	**CHAIR**: Cordelia Selomulya	
15:00h-15:15h	O9 – Francesca Duggan (University of Parma, Italy & University College Cork, Ireland) – Hybrid cold-set gels from dairy and lupin proteins: linking protein mixing ratio with rheological properties	O25 – Mingxin Wang (University of Leeds, UK) – Enzymatic hydrolysis: An approach to improve the lubrication properties of plant proteins	O41 – Patrick A. Rühs (ETH, Zürich) – Addressing multicomponent complexity in freeze structuring of food colloids	
15:15h-15:30h	O10 – Moawad Yara (Valrhona, CRT Agir, CRPP, France) – Role of Dispersion Type, Fat Phase, and Fiber Nature in the Texture and Stability of Model Chocolate Emulsions	O26 – Sai Prasanna (Indian Institute of Technology Tirupati, India) – From Fibre to Function: Cellulose Nanocrystals Extracted from Spent Coconut Fibres as Pickering Emulsion Stabilizers	O42 – Julian Fischer (BOKU University, Austria) – Inducing anisotropy in emulsion-filled hydrogels by unidirectional freezing	
15:30h-15:45h	O11 – Pascal Bertsch (University of Fribourg, Switzerland) – The Nano World of Espresso: Oil Droplets and Rigid Polymer Structures Shape the Shot	O27 – Rocío Morales-Medina (Technische Universität Berlin, Germany & University of Granada, Spain) – Combined enzymatic pre-treatment and microfluidization allow production of stable low-viscous suspensions of high-cellulosic dietary fibre by-products	O43 – Luuk Philipsen (Unilever Innovation Centre Wageningen & University of Amsterdam, the Netherlands) – Edible films from cellulose microfibrils and solid fats	**VISIT TO ALHAMBRA**
15:45h-16:00h	O12 – Christophe Chassenieux (Le Mans University, France) – Water in Water emulsions stabilized by cruciferin-based microgels and microcapsules	O28 – Astrid Penicaut (INRAE, France) – Emulsifying Properties of White Chlorella Biomass and Its Fractions after Cell Disruption by High-Pressure Homogenization	WILD FOOD TALK – Introduction and explanation to coffee break	
16:00h-16:30h	**COFFEE BREAK + POSTER SESSION**		**POSTER SESSION & ECO-FRIENDLY SNACK** Offered by WILD FOOD featuring plant based protein.	
	CHAIR: Julia Maldonado Valderrama	**CHAIR**: Patricia López Sánchez		
16:30h-16:45h	O13 – Sybren Zondervan (Wageningen University and Research, the Netherlands) – Switchable foam stability by Janus-like plant protein particles	O29 – Anahí Bonilla-Rodríguez (University of Lleida & Agrotecnio Center, Spain) – Pea protein hydrogels: influence of protein concentration, pH and ultrasound-assisted gelation		
16:45h-17:00h	O14 – Tobias Roebroek (KU Leuven, Belgium) – Balancing oil and protein content: antifoam regimes of foamed protein-based emulsions	O30 – Federico Casanova (Technical University of Denmark, Denmark) – Structural, Colloidal, and Functional Modifications of Coconut Protein Induced by Defatting: Roles		

* Lunch and coffee are served in posters area

	Monday 23rd	Tuesday 24th	Wednesday 25th	Thursday 26th
			TOPIC: Encapsulation, delivery, bioaccessibility and nutrition	VISIT TO ALHAMBRA
	CHAIR: Julia Maldonado Valderrama	**CHAIR**: Patricia López Sánchez	**CHAIR**: Adam Macierzanka	
17:00h-17:15h	O15 – Reinhard Miller (TU Darmstadt, Germany) – Dynamic and equilibrium surface layer properties of jujube (Ziziphus jujube) leaf extract	O31 – Ben Van den Wouwer (Ghent University & KU Leuven, Belgium) – Impact of lipid co-isolation and processing strategies on the yield and foaming functionality of soybean okara protein isolates	O44 – Larisa Tsarkova (DTNW & University of Duisburg-Essen, Germany) – Evaporation in bulk water, ethanol–water, and aroma–ethanol–water mixtures: interplay of geometry, composition, and interfacial processes	
17:15h-17:30h	O16 – Giulia Potenziani (University of Turin, Italy) – Botanical Extracts in Water-in-Oil Emulsions: A Natural Strategy to Enhance Sunflower Oil Oxidative Stability	O32 – Mauricio Oyarzún (University of Copenhagen, Denmark) – Behavior, Functionality and Digestibility of a Protein Concentrate, and Integration of Oil Bodies into Skim Milk: A Dual Study of Products from Hempseed Water-Only Fractionation	O45 – Prashant Kumar (Indian Institute of Technology Tirupati, India & Leibniz University Hannover, Germany) – Sustained Intestinal Release and Enhanced Bioaccessibility of Cinnamon Essential Oil from Cold Plasma-Modified Nanocarriers	
	CHAIR: Fatemeh Mirpoor	**CHAIR**: Francisco Rios Ruiz		
17:30h-17:45h	**Platinum Sponsor Wiley** F7 – Cindy Lalagüe (Université Laval) – Detailed characterization and gelation mechanism of mung bean albumin and globulin fractions.	F17 – Jasper H. Seibt (Technische Universität Dresden) – Heat-induced co-aggregation of rapeseed cruciferin with pea legumin and soy glycinin: Understanding protein interactions for clean-label applications. F18 – Raiane Rodrigues da Silva (State research institute Center for Physical Sciences and Technology) – Modification of pea albumin structure by pulsed electric field (PEF). F19 – Martina Klost (Technische Universität Berlin) – Acid induced gelation of pea protein: impact of protein pre-treatment and post-fermentation processing on gel properties.	O46 – Giulia D'Alessio (University of Teramo, Italy) – Tailoring pea protein functionality via high-pressure homogenization for stabilizing and spray-drying hop-enriched O/W emulsions	

* Lunch and coffee are served in posters area

	Monday 23rd	Tuesday 24th	Wednesday 25th	Thursday 26th
17:45h-18:00h	F8 – Jialin Sun (University of Leeds) – Understanding the development of food-grade antibacterial packaging film. F9 – Fatemeh Mirpoor (University of Reading) – Improvement of functional properties of hemp proteins by chemical and enzymatic modifications. F10 – Susana Guzmán-Puyol (Universidad de Málaga) – Agro-industrial avocado residues as functional additives for cellulose-based food packaging.	F20 – Raúl Pérez-Gálvez (University of Granada) – Tuning the emulsifying properties of sunflower and olive protein hydrolysates by enzymatic treatment and pH. F21 – Thais Gallo (INRAE) – Rheological behavior of acidified gels produced from faba bean protein concentrates. F22 – Pernille Koch (University of Copenhagen) – Mechanisms Responsible for Gelation during High-Temperature Treatment of Whey Protein Aggregates.	O47 – Fang Fang (Aarhus University, Denmark) – Interactive effects of polyphenols and artificial cell walls on starch transitions and starch and polyphenol bioaccessibility	**VISIT TO ALHAMBRA**
18:00h-18:30h	**POSTER SESSION & COCKTAIL** Sponsored by SABOR GRANADA: A Taste of Granada: featuring the finest local oils, wines, cheeses, vegetables and cured meats			
18:30h-19:00h				
19:00h-20:00h		**Walk together to Carmen de los Mártires**	**GUIDED VISIT: GRANADA WALKING TOUR**	
20:00h-20:30h		**GALA DINNER (Carmen de los Mártires)**		

* Lunch and coffee are served in posters area

PLENARY COMMUNICATION

Prediction and validation of emulsifying properties of peptides in oil-in-water emulsions.

Charlotte Jacobsen

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Food industry largely has relied on synthetic emulsifiers, phospholipids or proteins (egg, soy and dairy proteins) for production of food emulsions. However, due to the green transition there is an increasing interest in producing protein-based emulsifiers from side-streams or other new sustainable sources such as seaweed/microalgae, microbes and insects. Often emulsifying properties of proteins can be improved by enzymatic hydrolysis, which produces peptides with enhanced interfacial properties compared to the parent proteins. Traditionally, a trial-and-error top-down approach has been used to produce such emulsifying peptides. This approach involves evaluation of different proteases added either individually or in combination to obtain a range of protein hydrolysates with different degrees of hydrolysis. Subsequently, the hydrolysate is used directly or fractionated before the emulsifying activity is assessed. Such an approach is time-consuming and resource demanding. This presentation will discuss recent advances in a fundamentally different bottom-up strategy which is facilitated by quantitative proteomics and bioinformatic functionality prediction, to produce emulsifying peptides by targeted enzymatic hydrolysis. Results from studies using this approach on a range of different proteins (seaweed, potato, microbial, brewers spent grain) will be presented.

Functional and health aspects of plant protein - polysaccharide interactions

Anna Ström

Chemistry and Chemical Engineering, Chalmers University of Technology

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The development of sustainable, plant-based food is driven by the need for the food system to reduce its environmental impact and respect the planetary boundaries. In addition, consumer demands have driven increased interest in alternative proteins.
Plant proteins tend to aggregate in water dispersions, which leads to poor colloidal stability. Improved colloidal stabilization can be obtained by the addition of polysaccharides, building on the extensive knowledge obtained for colloidal stabilization of dairy – polysaccharide [1].
In this talk I will exemplify stabilization of plant proteins using polysaccharides, for soy and oat proteins. I will discuss the effect of stabilization as a function of polysaccharide structure and charge. The improved colloidal stabilization obtained for certain polysaccharides extends the processing window (heat treatment) of plant protein dispersions, thus adding techno-functionality.
The second part of the talk will cover work conducted within a national research consortium (PANSweden). The aim of the research carried out within the consortium is to understand the impact of plant protein on health-related aspects such as digestion and faecal fermentation. In this part I will show how the presence of polysaccharides impact in-vitro digestion and in-vitro faecal fermentation of proteins and polysaccharides. The proteins studied are oat and pea proteins, in combination with pectin and cellulose rich pea hull fibres. The products (ammonia, short chain fatty acid) of faecal fermentation as a function of the ratio of the cellulose rich pea hull fibre and pea protein will be discussed.

References:

[1] Dickinson E., Hydrocolloids at interfaces and the influence on the properties of dispersed systems, Food Hydrocolloids, 2003, 17: 25

From structure to nutrition: linking the multi-scale architecture of alternative food systems to their digestion mechanisms

Marta Martínez Sanz

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The transition towards more sustainable, diversified and health-oriented diets requires a mechanistic understanding of how the structure of alternative food sources governs their nutritional performance. In complex food colloids, proteins and polysaccharides are hierarchically arranged across multiple length scales, from molecular interactions to supramolecular assemblies and macroscopic networks. However, how this multi-scale architecture influences gastrointestinal digestion and subsequent nutrient transport remains poorly understood.

Addressing this gap requires a structural framework that connects the initial structural characteristics of alternative food systems with their digestion mechanisms and the nanoassembly of the resulting digestion products. By combining advanced structural techniques, including small-angle X-ray and neutron scattering (SAXS/SANS), with microscopy, rheology and compositional analysis, together with standardized *in vitro* digestion models, we are investigating how protein-polysaccharide interactions, cell wall architecture and matrix structure modulate enzymatic accessibility, proteolysis kinetics and nutrient release across different food systems. Our results show that digestion is not simply a process of molecular breakdown, but a dynamic structural reorganization. The progressive disassembly of food structures upon digestion leads to the formation of new nanoassemblies. Interactions between released peptides, soluble polysaccharides and bile salts promote the formation of distinct colloidal structures, including mixed micelles and lamellar phases. The nature and stability of these assemblies are strongly influenced by the initial matrix architecture and physicochemical properties of the digesta.

Altogether, this work demonstrates that digestion should be understood as a multi-scale structural transition. Understanding these transformations is essential to rationally design next-generation alternative food systems with tailored digestibility, nutrient bioaccessibility and metabolic functionality.

A new look at milk as a drug delivery system, through the lens of lipid digestion

Ben J. Boyd

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The drug development process biases towards poorly-water soluble and often highly lipophilic drugs. One of the tools a our disposal for improving their delivery is through formulation in lipid based delivery systems. These materials often contain high amounts of surfactants and co-solvents, presenting toxicity limitations, lss of solvency on dispersion in the gastrointestinal tract and failed delivery through drug precipitation. Of course we missed the obvious- in most cases Nature has overcome these delivery challenges using milk. While milk has been previously investigated as a drug delivery system it has never progressed, in large part because of a lack of consideration of digestion as a critical component of behaviour. We have been using in situ analytical techniques to study the dissolution and delivery of poorly soluble drugs using milk, infant formula and related drinks, with a specific focus on the interaction of drug with digesting lipid components. While these systems are particularly amenable to delivery of weakly basic drugs due to ion pairing with liberated fatty acids during digestion, we have found surprisingly promising effects with acidic and non-ionisable drugs due to enhanced affinity for the colloidal structures formed during digestion enabling the drug to dissolve and remain dissolved and in an absorbable form after digestion where 'synthetic' lipid formulations have failed. The studies provide a pathway for renewed interest in milk and related materials in drug delivery and importantly offer a pediatric friendly class of excipients to better serve this neglected population in the pharmaceutical landscape.

KEYNOTE COMMUNICATION

Monitoring dynamic processes in food using microfluidics

Karin Schroen, Meinou Corstens, Boxin Deng

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Humanity faces the huge challenge to supply a growing world population with sufficient and healthy food. To make this a reality we need to rethink how we produce food at large scale. This implies rethinking production 'on the land/in the greenhouse', fractionating raw materials, understanding their functionality during processes used in food production, as well as under digestive conditions to make the connection to health effects that can be created by smart food design.
Today's presentation will focus on investigation of processes that take place at micrometer scale, and even smaller scales, and often within very short times. These processes underly the food structure that we get, but the dynamics thereof are very difficult to capture due to time and size challenges. Most examples that I will discuss use microfluidic tools to visualized these processes. For example, for formation of two phase systems such as emulsions and foams, and that also includes their digestion, and the control thereof by clever food structure design.
I hope to discuss with you how these techniques can contribute to more flexible use of ingredients. For example, replacement of animal-based products with their plant-based counterparts, and the used of other streams that are currently considered waist but can truly contribute to more sustainable food production practice. I am convinced that the techniques developed are ultimately used to do fast screening, will allow comparison of ingredients, link with digestion, and connect with more classic processing technologies (e.g., high pressure homogenization) thus contributing to smart food design.

Keywords:

Sustainable food processing, microfluidic analysis, alternative proteins, food digestion, high speed imaging

Hydrogel Model Systems to Decode Polysaccharide Interactions and Rheology in Seaweeds

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Seaweeds are gaining increasing attention as sustainable, multifunctional ingredients for the next generation of food products. However, the complexity of their native cell wall architectures continues to limit their rational use in food formulations. We will present a hydrogel-based approach to understand the structural and rheological properties of seaweed cell walls, with a focus on cell wall rehydration, dynamics, and polysaccharide interactions. Model systems built from bacterial cellulose [1] alginate, and fucoidan serve as controlled networks to probe how composition, architecture, and ionic environments influence gel formation and viscoelastic responses. These insights will be linked to the behaviour of whole seaweed dispersions [2], where synergistic interactions among cell-wall polymers modulate structure, flow, and functionality. Rheological measurements across scales *i.e* from hydrated gels to reconstituted suspensions will be discussed in relation to texture, water retention, and structural resilience. Special attention will be given to the parallels and contrasts between purified polysaccharide gels and the complex matrices found in intact seaweed tissues. By bridging model hydrogel systems with real seaweed dispersions, this work lays the foundation for designing seaweed-based ingredients with tailored properties for food applications. The findings open new opportunities to harness polysaccharide diversity in seaweeds for structuring, and stabilisation in clean-label formulations, while advancing our fundamental understanding of algal cell-wall organization.

Keywords:
Seaweed, polysaccharides, hydrogels, bacterial cellulose, rheology

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Delubrication by plant proteins: Understanding and addressing using colloidal technologies

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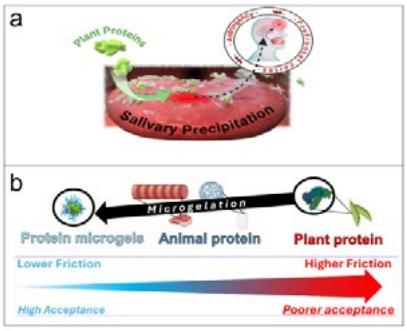
Oral lubrication plays a critical role in food perception and consumer acceptance, yet it remains an underexplored dimension in food innovation. Astringency, a dry, rough mouthfeel resulting from poor oral lubrication, is a major sensory barrier to the acceptance of plant-based proteins, with its underlying mechanisms still poorly understood. We present a multiscale investigation into plant protein-induced delubrication, integrating sensory evaluation (n = 100), neural imaging via functional near-infrared spectroscopy (fNIRS; n = 29), and cellular assays to reveal how salivary protein-protein hydrophobic interactions leads to astringency and increases oral friction.
By understanding these tribological principles in food, including *in vitro* friction measurements on 3D-printed tongue-like surfaces, we demonstrate colloidal technology solutions such as microgelation and polysaccharide self-assembly that can reduce or remove astringency mouthfeel. Remarkably, these microgel colloids, composed of up to 95% water, achieve ultra-lubricating properties comparable to fat, improving not only plant protein application but with calorie reduction possibilities. These oral tribology led approaches have catalysed innovation, including the formation of a university spin out company, *Microlub* , which reimagines food design based on lubrication rather than taste alone. These findings underscore the critical role of oral tribology in sensory perception and offer a pathway to enhance the palatability, acceptance and health aspects of sustainable protein products.

Keywords:
Plant protein, Sensory, Microgels, Sustainable protein, Tribology, Neural imaging



a) The issue of plant protein astringency resulting from protein-protein hydrophobic interactions in the mouth b) A solution for plant protein astringency in microgelation processing underscoring the importance of oral tribology in food design for the adoption of alternative protein foods

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The role of serum properties in juiciness perception of plant-based meat analogues

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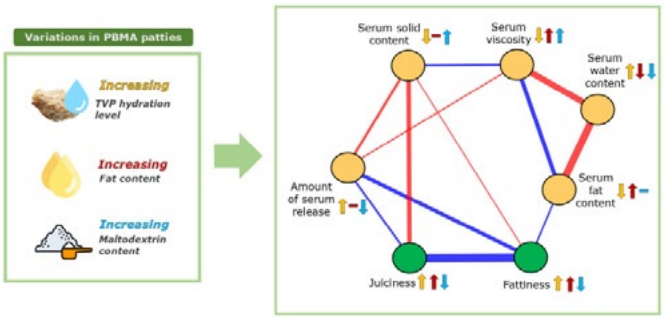
Plant-based meat analogues (PBMA) play a crucial role in driving the protein transition, but their market growth is hindered by sensory limitations. In particular, a lack of juiciness and fattiness remain major barriers to consumer acceptance. Previous studies showed that these attributes correlate strongly with the amount of released serum (expressible fluid) during mastication. However, the role of serum properties on those attributes still remains unclear. This study aimed to reveal the separate effects of serum quantity, composition and viscosity on the perception of PBMA patties, identifying the mechanisms behind juiciness and fattiness. Serum properties were varied by altering the hydration level of textured vegetable proteins (TVPs), fat and maltodextrin content of raw patties. This resulted in quantity of released serum ranging from 8 to 20 %w/w, fat content from 12 to 65 %w/w, and serum viscosity from 6 to 360 mPa·s. These variations allowed us to identify which parameters contributed most to different sensory attributes. While serum quantity strongly influenced perception, serum composition also played a role. Especially, fattiness was driven by the content, while juiciness remained unaffected. By using network analysis via undirected graphical models (UGMs), we were able to verify that this effect was not related to viscosity enhancement of fat droplets, but mostly through other effects, such as lubrication. We will further discuss how juiciness and fattiness thus arise from different mechanisms, and how these attributes may be modulated.

Keywords:

Plant-based meat analogues, juiciness, fattiness, rheology, texture



Graphical abstract

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Emulsifier Saturation Modulates Interfacial Monoglyceride Crystallisation and Polymorphic Transitions

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Monoglyceride crystals play a critical role in stabilising food emulsions through their interfacial activity at oil-water interfaces. However, the presence of co-emulsifiers can significantly alter monoglyceride crystallisation behaviour, with effects that vary depending on emulsifier molecular structure. This study investigates how emulsifier saturation influences the interfacial crystallisation of glycerol monostearate (GMS) using a powerful combination of Profile Analysis Tensiometry (PAT) and synchrotron-based Small- and Wide-Angle X-ray Scattering (SAXS/WAXS). Two polysorbate emulsifiers with identical C18 chain lengths but differing saturation: Polysorbate 60 (Tween® 60, fully saturated) and Polysorbate 80 (Tween® 80, monounsaturated), were compared at an isolated oil-water interface. PAT measurements revealed that Tween® 80 significantly inhibited GMS crystallisation, delaying the onset of interfacial crystal activity to 13.8 °C compared to 16.5 °C with Tween® 60. Synchronised SAXS/WAXS analysis captured the structural evolution of interfacial GMS crystals in real-time, revealing a polymorphic transition from sub-α to β prime phase that increased crystal hydrophobicity. These findings demonstrate that even subtle differences in co-emulsifier structure, specifically the presence of a single double bond, can profoundly affect the temperature, kinetics, and polymorphic behaviour of interfacial lipid crystallisation. This integrated PAT-SAXS/WAXS approach provides unprecedented insight into interfacial crystallisation dynamics and offers a powerful framework for rational emulsion design in food systems.

Keywords:
Interfacial crystallisation, monoglycerides, polysorbates, PAT, SAXS/WAXS, emulsion stability, polymorphism

Impact of functional properties and thermo-mechanical pre-treatment on freeze structured fibrous pea protein isolate textures

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Freeze structuring creates porous and fibrous structures by controlling the growth of ice crystals within an aqueous suspension in one direction. The solids are concentrated between the needle-like ice crystals. Measures to preserve the anisotropy for high moisture fibrous plant protein textures include chemical and enzymatic crosslinking. Here we report on the impact of the functional properties of commercial pea protein isolates on freeze-structured textures fixed by melting in calcium brine or as the result of a thermo-mechanical pre-treatment; the formulations did not contain added polysaccharides. Anisotropy was assessed by texture analysis and imaging including the use of X-ray tomography. A 20 wt% suspension of a pea protein isolate with a solubility of 5.5 ± 0.2 wt% at pH6.8 (based on a starting concentration of 2 wt%) and processed at this pH resulted in disordered and not self-supporting final textures, whereas highly ordered and firm textures were successfully prepared at alkaline pH. While a 20 wt% suspension of a higher solubility pea protein isolate could not be structured (22.8 ± 0.5 wt%, pH8), combining the two protein isolates (pH7.2) and freeze structuring provided fibrous self-supporting textures. It appears insoluble protein plays a key role alongside soluble protein in obtaining the desired textures. Soley mechanical as well as thermo-mechanical pre-treatment of the combined protein suspension allowed freeze structuring at higher protein content, probably due to a lower overall viscosity of the sheared (and heated) suspension system. The results will be discussed in the context of water holding capacity and freezable water content.

Hyperspectral Imaging: "Night Vision" that unlocks emulsion stability monitoring in complex systems.

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The advance of AI and digital technologies promises a new evolution to unlock understanding in complex colloid systems. Whilst there has been much focus on AI algorithms, there are impressive developments in new sensing technologies. Hyperspectral imaging with its near infrared wavelengths overcomes multiple scattering enabling detailed study of complex colloidal systems. Maintaining the stability of emulsion based products - such as coffee creamers and nutritional beverages - is critical for consumer trust and global distribution. Yet, conventional light-scattering methods fail to detect early-stage defects in concentrated systems. This work introduces hyperspectral imaging (400–1700 nm) as a transformative, non-destructive tool for real-time stability monitoring. By capturing spectral fingerprints across visible and short-wave infrared regions, we quantified fat volume fractions (1–62.5%) and tracked structural changes during creaming and acid-induced aggregation. Key wavelengths (975 nm and 1525 nm) emerged as high-sensitivity markers for dilute and concentrated regimes, enabling precise detection where traditional methods plateau. Using these new spectral finger prints we were able to study the destabilisation dynamics of concentrated emulsions and show that they diverge from Stokes' predictions at high packing densities, revealing complex dynamics beyond viscosity effects. In dilute emulsions, aggregation altered reflectance signatures, offering a novel pathway for kinetic monitoring. These findings position hyperspectral imaging as a next-generation quality control technology—combining chemical insight with spatial resolution to predict defects before they become visible. This approach opens new horizons for studying the dynamics of concentrated colloidal systems and especially when combined with automation and AI spectral analysis.

Keywords:
Hyperspectral imaging, multispectral imaging, emulsion stability, creaming kinetics, near infrared spectroscopy.

Acknowledgements:
This work was funded by Nestlé SPN who is a manufacturer of packaged foods products where the contents of this research can be used.

ORAL COMMUNICATION

Linking colloidal structure to antioxidant function in legume protein-stabilised emulsions

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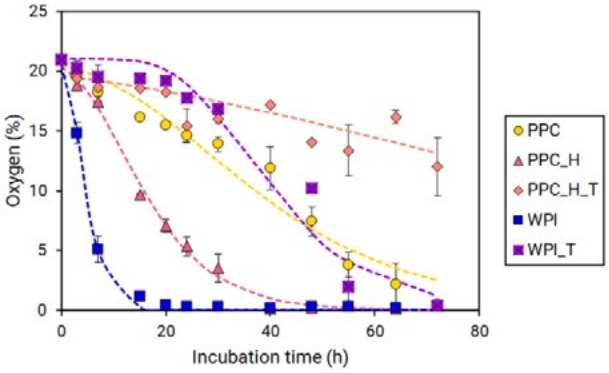
Current environmental challenges are driving a transition from animal-based to plant-based proteins in food applications, which has been particularly prominent in dairy protein-stabilised oil-in-water (O/W) emulsions such as milk or cheese analogues. The use of legume protein ingredients to stabilise O/W emulsions has been largely documented, focussing mainly on differences in emulsion structure and physical stability. In the present study, faba bean and pea protein concentrates and isolates were compared to whey protein isolate (WPI) for their ability to physically and oxidatively stabilise emulsions. Legume protein-stabilised emulsions were found to be prone to flocculation and subsequent coalescence, which was linked to a less negative droplet zeta potential as compared to WPI-stabilised emulsions. Once these physical properties were established, we thoroughly investigated the oxidative stability of the oil droplets in relation to the colloidal structure of the protein ingredients and to their detailed chemical composition. Legume protein-stabilised emulsions had enhanced oxidative stability compared to the WPI-based systems, which was attributed to the presence of various co-passenger molecules in the legume protein ingredients (tocopherols, phytic acid, polyphenols) that may act as antioxidants. Using pea protein concentrate as a model, endogenous tocopherols were found to be effective in delaying lipid oxidation reactions in emulsions. A similar concentration of exogenously added tocopherols was even more effective in that respect. This suggests that, beyond the tocopherol content, their physical organisation may tune their antioxidant activity. Our findings suggest that endogenous tocopherols in legume protein ingredients occur in protein-lipid aggregates, which could limit their antioxidant potential towards oil droplets. This study highlights how the physical organisation of plant protein-based emulsions at the colloidal scale impacts not only their physical stability, but also the availability and efficiency of chemically active endogenous molecules.



Oxygen uptake of 1 wt.% protein 10 wt.% linseed oil-in-water emulsion incubated at 25°C. PPC = pea protein concentrate-based emulsion, PPC_H = PPC stripped of endogenous tocopherol, PPC_H_T = PPC_H with added tocopherol, WPI = whey protein isolate-based emulsion, WPI_T = WPI with added tocopherol

Acknowledgements:
This work benefits of the financial support of the French government through the National Research Agency (ANR) as part of France 2023 in the framework of LETSPROSEED ANR-22-PELG-002, and the financial support of INRAE for the Ph.D. thesis of JK.

Food-Grade Nanoemulsions Formed with Triacylglycerols and Different Biosurfactants as Stabilisers

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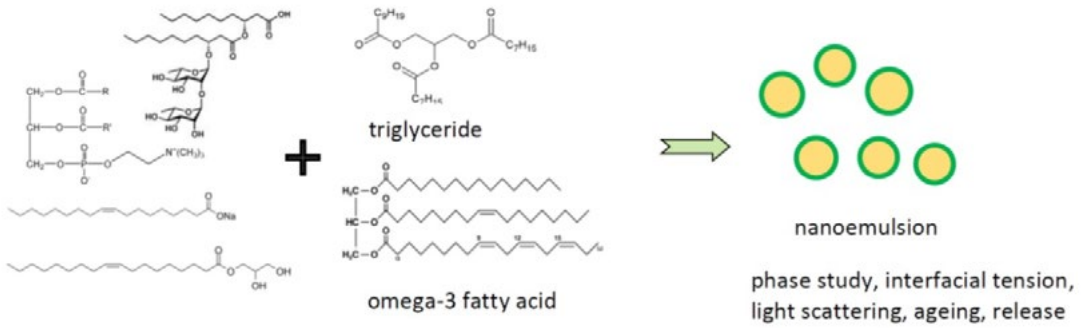
Oil-in-water emulsions, able to deliver valuable nutrients, e.g. omega-3 fatty acids, are interesting components in food science. However, the formulation of colloidally stable emulsions of sufficient stability can be a major challenge and this even more so when using food grade oils, such as triacylglycerols. One way to address this challenge can be to employ nanoemulsions. With their small diameter of 50-400 nm they are typically kinetically rather stable and with high surface/volume ratio they often have the advantage of fast release of active ingredients.
In this work, we studied a wider range of amphiphiles, such as soy lecithin, Tween 80, rhamnolipid, glycerine monooleate (GMO), sodium taurate, and sodium oleate with respect to their ability to function as stabilisers for nanoemulsions. Lecithin has a tendency to form bilayers in aqueous solution, while the others form micelles. In our experiments we determined the interfacial tension (IFT), as an important parameter for describing the solubilisation properties, against caprylic/capric triglyceride and paraffine oil as a function of surfactant concentration and also for mixtures of them. In the mixtures marked synergistic effects in reducing the IFT were observed by appropriately mixing the different components, especially for combinations of nonionic and ionic surfactant. Emulsification was done by sonication and vortexing for samples around the minimum IFT values. The formed (nano)emulsions were characterised with respect to their size and ageing behaviour by means of light scattering experiments. The size of stable droplets was in the range of 100 to 150 nm. In general, the droplet sizes are the smaller the lower the IFT, but the colloidal stability of the droplets typically depends selectively on the choice of the surfactants and their mixing ratio. In summary, this means that droplet size and stability of these food-grade emulsions can be tailored by appropriately choosing the composition of the amphiphilic mixture.

Keywords:
nanoemulsions, stability, delivery of omega-3-fatty acid



Scheme of formation and characterisation of omega-3 fatty acid containing triglyceride (nano)emulsions with different surfactants as stabilisers.

Association of endogenous phospholipids with pea globulins: effect on their structure and functionality

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While extraction methods aim to enrich plant protein fractions, residual lipids often persist. Phospholipids, with their amphiphilic nature and high surface activity, have the potential to significantly alter protein–protein and protein–interface interactions, and yet their contribution to protein structure and functionality remains poorly defined.
In this study, we report the role of endogenous phospholipids on pea globulins (legumin and vicilin) structure, solubility, heat stability and foaming properties. Globulins were extracted from both defatted and non-defatted pea protein concentrates and further fractionated by selective pH precipitation with borate buffer. Lipid analysis revealed that non-defatted globulins still contained ~7% lipids, predominantly phospholipids, with higher levels detected in the legumin-rich fraction than in vicilin.
Structural characterization using synchrotron radiation circular dichroism, nano-differential scanning calorimetry and small angle X-ray scattering showed that legumin had higher α-helical content and greater thermal stability than vicilin, regardless of lipid content. Furthermore, both legumin and vicilin showed monomers dissociation and unfolding with heating, before the formation of heat-induced aggregates, with no difference between the proteins extracted from defatted flour, compared to the non-defatted proteins. In spite of the identical structural features of proteins, the presence of the endogenous phospholipids reduced protein solubility, affected interfacial adsorption properties and impaired foaming performance. These results demonstrate that lipids are co-extracted with legumin and influence their interfacial behavior. By disentangling the effects of endogenous phospholipids from intrinsic protein properties, this study highlights the significant impact of co-extracted lipids on pea protein functionality. These findings underscore the importance of considering lipid–protein interactions when designing plant protein ingredients for targeted applications.

Keywords:
Pea protein; Legumin; Vicilin; Phospholipids; Lipid–protein interactions; Interfacial functionality

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Influence of phospholipids and a novel vegetable oil blend on the formation and quality of faba protein-stabilized plant-based whipped cream

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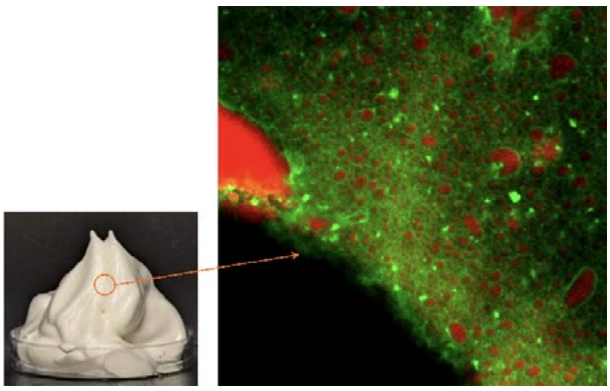
This study aims to evaluate the effects of two types of phospholipids and an experimentally developed novel healthy vegetable oil blend on the properties of faba bean protein-stabilized plant-based whipped cream without relying on any gums. Interfacial protein displacement by the phospholipids in a 30 wt% oil-in-water (O/W) emulsion showed that only the phosphatidylinositol (PI)-rich phospholipid could displace proteins from the oil droplet interface, while the phosphatidylcholine (PC)-rich phospholipid had no effect [1]. The presence of PI facilitated a kinetically favourable reduction in interfacial tension. Protein alone did not influence the fat crystal contact angle in the aqueous phase, which was significantly reduced by PI. The contact angle range indicated that fat crystals were preferentially wetted by liquid oil.
Oil-in-water cream emulsions were prepared with a 30 wt% oil blend containing PI and a 70 wt% aqueous phase with faba bean proteins using a high-pressure homogenizer. After storing for one week in a refrigerator (4°C), the emulsions were whipped using an automatic whipping machine, and the stability, rheology, overrun, and stabilization mechanisms of the plant-based whipped cream were examined. As a control, a dairy whipped cream made from 35% fat-based cream was used. The proportions of crystallized fat in emulsions prepared with the oil blend at 4°C were favourable for partial coalescence, achieving the desired crystallization and melting points [2]. The plant-based whipped cream with PI achieved a peak overrun twice that of the dairy cream, with less serum loss; however, it took longer to reach this peak than the dairy cream. At peak overrun, it showed viscoelastic strength comparable to that of dairy whipped cream. Confocal microscopy confirmed that fat crystal-induced partial coalescence and protein-induced bridging flocculation caused droplet aggregates to form a network, stabilizing air bubbles and creating a stable 3D structure of plant-based whipped cream. This study demonstrates that plant-based cream emulsions can be just as functional as their dairy counterparts without requiring the addition of food gums, thickeners, or synthetic emulsifiers.

Keywords:
pulse protein, cream emulsion, fat crystallization, interfacial tension, contact angle, solid fat content



Visual observation and microstructure of faba protein-stabilized plant-based whipped cream

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Acknowledgements:
This research was funded by the Agriculture Development Fund grant by the Saskatchewan Ministry of Agriculture, with financial support provided under the Sustainable Canadian Agricultural Partnership, a Federal-Provincial-Territorial initiative.

Coalescence in Pickering emulsions: influence of deacetylation of chitin nanoparticles and dispersed phase fraction investigated by microfluidic techniques

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Chitin nanoparticles (ChNPs), derived from renewable biopolymers, are promising Pickering stabilizers due to their biocompatibility and tunable surface properties. Pickering emulsions are known for their long-term stability compared to conventional emulsifiers. However, the role of particles in early droplet stabilization remains poorly understood, as in large-scale emulsification, droplet formation and coalescence occur at the same time. In this study, we used a **microfluidic T-junction device** in which we could de-couple the formation and coalescence processes at short time-scales. We varied the surface composition of ChNPs by deacetylating and testing them at low (~10%) and high (>50%) dispersed phase fractions (ϕ) to monitor droplet coalescence.
We show that the treatement of **deacetylation reduced droplet coalescence,** likely due to improved particle adsorption and an increase in zeta potential from +29.9 mV to +43.1 mV. In addition, **higher dispersed phase fractions led to prolonged droplet interaction times and contact frequency** (*e.g* ., at ϕ = 0.55, some droplets interacted in pairs, while at ϕ = 0.75, as many as five surrounding droplets were observed), thus enhancing coalescence. Overall, our findings demonstrate how particle surface properties and dispersed phase fraction together determine interfacial coverage and coalescence resistance, which provides mechanistic insights for the critical design of robust biobased Pickering emulsions.

Keywords:
Pickering emulsions, chitin nanoparticles, microfluidics, droplet coalescence, particle adsorption

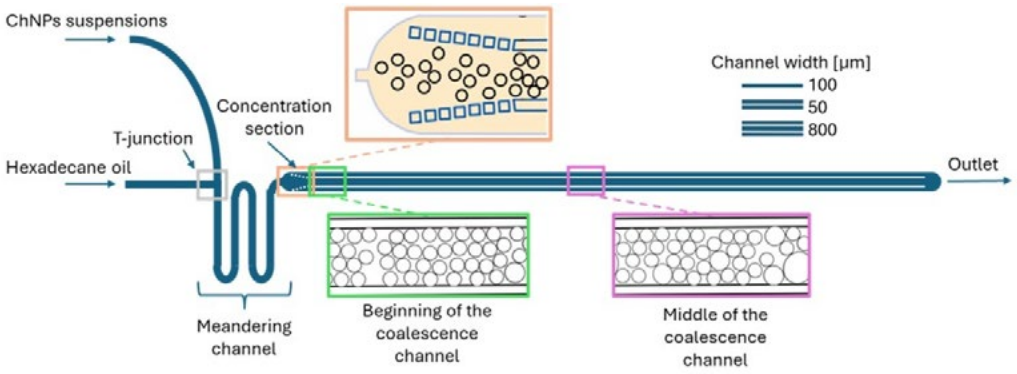

Fig. 1. Layout of the microfluidic chip with four sections: a T-junction, a meandering channel (after the T-junction), a concentration section, and a coalescence channel in which at various positions observations can be done. The channel height is 45 µm throughout the chip.

Acknowledgements:
This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No. 956248.

Atomic force microscopy of undried Pickering emulsions at the nm and µm scale

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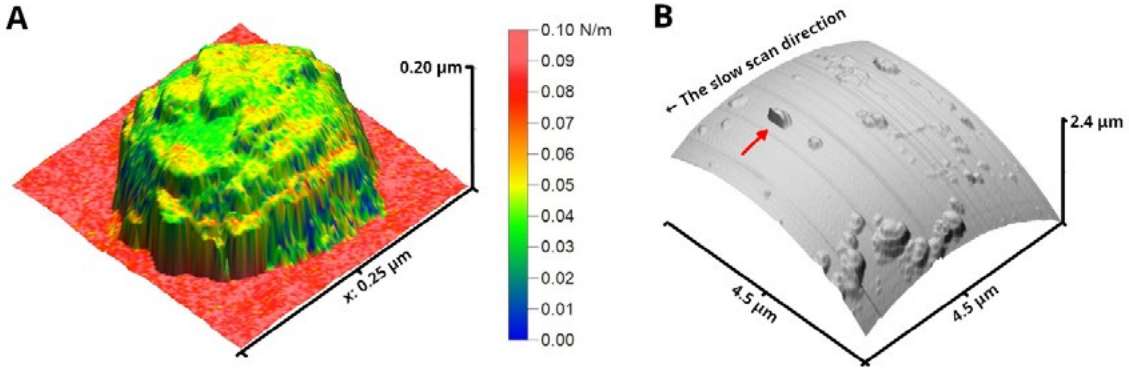
Atomic Force Microscopy (AFM) can measure delicate interfaces and their mechanical properties in nanoscale detail. We recently showed that real-world emulsions with interfacial nanoparticles ("Pickering emulsions") can be analyzed, moved, and merged under water with AFM (Fig. 1A). [1] Lignin (LNP) and silica nanoparticles (SiNP) were used to compare the behavior of soft biomatter to that of rigid inorganic particles. Interfacial LNPs were smaller than the LNPs before emulsification (ø ~100 nm), and they may have been partially smeared in the interface, while rigid SiNPs remained the same size and shape as the originals. Building on this, we now expand the results to a larger droplet size class, from 1 µm up to 10 µm wide, that have been prepared with a low-energy microfluidic method. [2] Surprisingly, LNPs were even more varied in size and how they behaved in the interface than the LNPs in the small droplets prepared by ultrasonication: the larger-droplet LNPs had aggregates, and some LNPs detached during the imaging (Fig. 1B). Clearly, there is more to be found on the interfacial behavior of soft bioparticles, which often are presumed to be intact, well-attached, or separate from each other in the interface. Besides presenting results, I will discuss general opportunities and pitfalls in AFM analysis of Pickering emulsions. The opportunities include high-detail topographical data perfectly aligned with mechanical data, and the option to mechanically manipulate the sample droplets and interfacial nanoparticles during the measurement. The pitfalls include unintentional alterations in the sample caused by the measurement. These problems are more prominent with droplets taller than the AFM tip, droplets with low coverage by the interfacial particles, and occasionally with micron-scaled droplets for a reason that remains to be resolved.

Keywords:
Atomic force microscopy, emulsion, Pickering emulsion, interfacial particles, lignin



AFM micrographs of oil droplets under water. A) Near-nanoscale droplet with LNPs with the surface stiffness data overlay.[1] B) LNPs of various sizes on the micron-scaled droplet interface. A nanoparticle was suddenly lost from the interface (red arrow) despite the interaction forces being small.

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Acknowledgements:
This work has received funding from ERC Consolidator grant (ID: 863808, "PARTIFACE") and Marie Skłodowska-Curie grant agreement (No. 956248).

Tuning the Mechanical Properties of Emulsions with Adhesive Protein Nanoparticles

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Emulsions are used for a wide range of products including cosmetics, pharmaceuticals, and food, each with their own mechanical requirements [1]. For instance, sunscreen should flow out of a bottle when squeezed but not drip off your skin. To thicken emulsions, one can reduce the mobility of emulsion droplets by increasing the droplet volume fraction or increasing the viscosity of the continuous phase [2]. However, not only the thickness is important, but also other rheological properties, such as yield stress, to provide enough solid-like properties in rest, while yielding at higher shear rates. To accommodate this, the attractive interactions between emulsion droplets might be increased using adhesive particles that link droplets under the right conditions. Such adhesive particles can be made by rapid acidification. When such particles are introduced, they can enhance the mechanical strength of emulsions by >100-fold (from a G' of 18.5 to 3159), providing enough stability to be suitable for 3D printing. On-chip microfluidic experiments revealed irreversible droplet-linking only occurred upon increasing ionic strength, i.e. screening surface charges, showing that electrostatic repulsions hindered the nanoparticle adhesivity. To explain this, we zoomed in on a single interface, where interfaces with nanoparticles became more elastic upon increasing ionic strength, likely through lateral interactions with other components via hydrophobic and van der Waals forces. Using a thin film balance, we validated these findings by measuring distinct adhesion between two interfaces with nanoparticles and no adhesion for interfaces without nanoparticles. Our results demonstrate how the mechanical properties of emulsions with protein nanoparticles can be tuned via ionic strength, highlighting the potential of protein nanoparticles in formulating stimuli-responsive emulsions.

Keywords:
Nanoparticles, Adhesion, Thin Film Balance, 3D Printing, Emulsions, Microfluidics

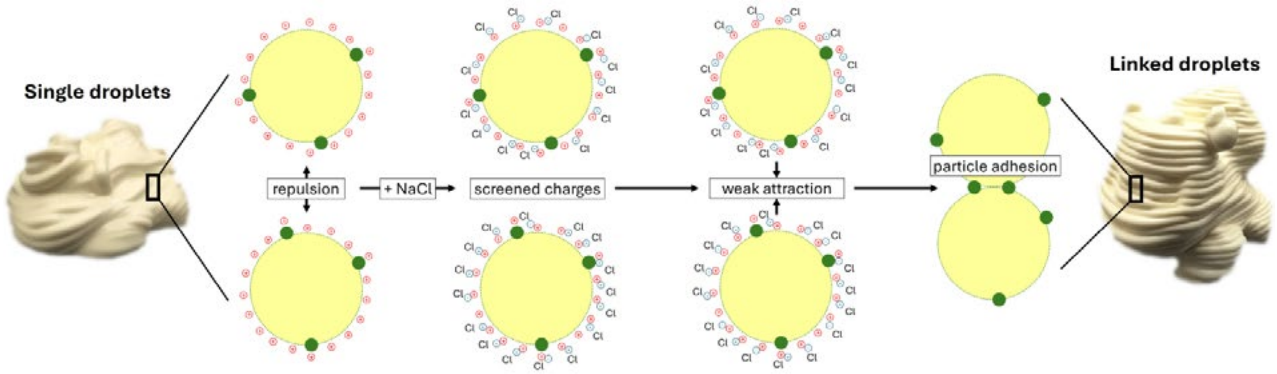

Figure 1: Graphical abstract highlighting the proposed mechanism for particle mediated linking of emulsion droplets and its effect on the mechanical properties of emulsions.

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Microbubble powders using freeze-dried Pickering emulsions

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Microbubbles are a widely used material in food formulations, as well as in various biomedical and pharmaceutical applications. Typically, microbubbles stabilized by surfactants and proteins tend to coalesce, break, and coarsen quickly. In contrast, microbubbles stabilized by solid nanoparticles, known as Pickering-stabilized microbubbles, can exhibit significantly better stability. Such microbubbles are often produced by directly dispersing gas into a nanoparticle dispersion and allowing the dispersed nanoparticles to adsorb at the air-liquid interface. However, the yield of such a process is low, as a significant amount of gas is lost. In addition, the resulting bubbles are often rather large with a wide size distribution, which decreases the shelf life through Ostwald ripening [2]. To improve the yield and stability of microbubbles, we present an alternative method here. First, we create an oil-in-water (O/W) emulsion, which is known for its high stability and uniform size distribution [3]. After this step, we remove water by freeze-drying, leaving a microbubble powder behind.
In this work, we investigated the potential of different nanoparticles and different volatile oils to prepare stable microbubbles. When hydrophobic silica nanoparticles were used, the produced microbubbles remained stable for up to a week, both in water and solutions with enhanced osmotic pressure. As a more sustainable alternative to silica particles, we also used modified hydrophobic calcium carbonate ($CaCO_3$) nanoparticles. Surprisingly, we achieved a series of even more stable microbubbles that remained intact for over a month. Also, the type of oil used influenced the properties of the microbubbles. This work highlights that the Pickering emulsion template method proves to be an excellent approach for preparing microbubbles, and that the properties can be tuned using different particles and oils. Also, food-grade microbubbles can be prepared.

Keywords:
Microbubble, Pickering-stabilized, hydrophobic nanoparticles, freeze-drying

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Hybrid cold-set gels from dairy and lupin proteins: linking protein mixing ratio with rheological properties

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The partial substitution of dairy proteins with plant proteins offers a promising route towards innovative and more sustainable food systems (Hinderink et al., 2021). Although combinations of dairy and plant have been widely studied (Lima Nascimento et al., 2023), the effects of blending plant and dairy proteins on the functional properties of hybrid systems remains underexplored. This work aimed to elucidate the impact of incorporating lupin protein isolate (L) into dairy protein solutions, composed of whey (W) and casein (C) proteins, focusing on the microstructure, linear and nonlinear rheological properties of cold-set gels made therefrom. Hybrid protein suspensions were formulated by blending L with W, C, and W:C blends (3W:1C, 2W:2C, 1W:3C), prior to acid-induced gelation with glucono-δ-lactone (GDL).
Gelation kinetics indicated synergistic effects between whey and casein, as 3W:1C and 2W:2C hybrids achieved higher storage moduli (G′ ≈ 1.8–2.2 kPa at 1 Hz) than individual ingredients (0.9 and 0.1 kPa in W and C, respectively). Hybrid gels showed enhanced gel strength, with L:W and L:(3W:1C) forming the strongest networks (G′ = 3.1 and 2.9 kPa at 1 Hz), indicating the reinforcing effect of lupin incorporation. Lissajous-Bowditch figures, obtained from LAOS analysis, revealed that all samples exhibited plastic deformation behaviour, progressively transitioning towards a rectangular shape at strain amplitudes between 627 and 994%. At lower strain levels (25-40%), all gels displayed elongated ellipses with curved edges, and a noticeable inclination of the stress–strain trajectory, indicating that shear stiffening occurred in all samples. Lupin:dairy hybrid gels exhibited narrower curves at low strain and delayed yielding, suggesting improved structural resilience to strain when lupin proteins were added to the gels. The most resistant system was L(3W:1C), that maintained elastic traits up to 627% of strain. To elucidate differences among samples, nonlinear elastic responses, as a function of strain amplitud e , were quantified by calculating the energy dissipation ratio (EDR). EDR results showed that all W:C blends displayed delayed energy dissipation compared to W and C, therefore indicating enhanced structural resistance, while L:W and L(3W:1C), which had the highest G′, showed the earliest EDR increase. Confocal microscopy revealed that W formed a highly compact and homogeneous protein network, whereas C gels exhibited a more open and heterogeneous microstructure, indicative of a weaker and less interconnected matrix. W:C blends had intermediate morphologies, with 3W:1C resembling the continuous structure of W, while 2W:2C and 1W:3C showed coarser networks, more similar to those of C. The incorporation of lupin proteins resulted in more dense and cohesive microstructures in L:W and L(3W:1C), suggesting enhanced protein–protein interactions and network crosslinking, while the gels with a higher concentration of casein exhibited a less continuous network, reflecting reduced structural compactness and connectivity.
These findings demonstrated that combining W:C blends with lupin proteins additionally reinforced the gel network and shifted the energy dissipation to higher values of strain amplitude. Such synergistic interactions highlighted the potential of dairy and plant protein hybrid gels to be tailored through formulation design, enabling the achievement of structures with desired rheological properties, that can be adapted to specific processing requirements or target textural attributes in food applications.

Keywords:
Lupin, dairy, protein, cold-set gel, rheology, microstructure

References:

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Role of Dispersion Type, Fat Phase, and Fiber Nature in the Texture and Stability of Model Chocolate Emulsions

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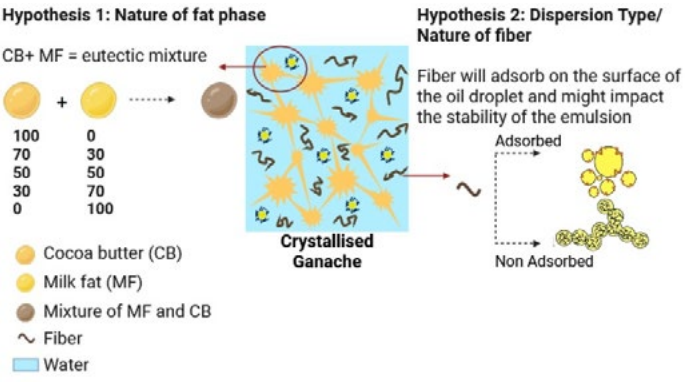
Ganache is a classic chocolate preparation widely used as a filling in biscuits, pastries, and confectioneries. Fundamentally, ganache is an emulsion composed of chocolate, sugar, and cream. According to Saglio et al. (2018) [1], freshly prepared hot ganache forms an Oil-in-Water emulsion, which transitions into a bicontinuous system upon cooling. The fat phase in ganache primarily consists of cocoa butter and milk fat. When combined, these fats may form a new eutectic fat phase, significantly affecting melting temperature and crystallinity, and consequently influencing both microstructure and macroscopic texture. Besides, the presence of fibers in ganache can also further modulate the emulsified state: fibers help to improve the texture and to maintain dispersed droplets depending on their localization, whereas their absence might lead to increased partial coalescence [2].
This study aims to elucidate the specific roles of fat composition and fiber type in shaping the microstructure and thermal properties of ganache. First, the influence of different fat blends on melting behavior, crystallinity, texture, and emulsion stability was studied. Second, the effect of fiber type on emulsion stability through particle adsorption at the interface or increase of viscosity and on overall texture has been examined. The influence of fibers was assessed under several conditions, including their presence or absence and their localization (at the interface vs. in the continuous phase).
The results obtained so far indicate that both fat composition and fiber type might influence the stability and texture of the emulsion.

Keywords:
Ganache, Fat, Fiber, Cocoa Butter, Milk Fat, Emulsions, Interface



Summary of the Hypothesis regarding the effect of the dispersion Type, Fat Phase, and Fiber Nature in Chocolate ganaches

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The Nano World of Espresso: Oil Droplets and Rigid Polymer Structures Shape the Shot

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Coffee is one of the most popular beverages worldwide, and the preparation of the perfect espresso has become an entire culinary discipline that combines science and craftsmanship. Espresso involves the extraction of finely ground coffee under high pressure, yielding a concentrated coffee rich in emulsified lipids, polysaccharides, and solids that contribute to its unique aroma and mouthfeel. While the aroma and flavor compounds in coffee have been meticulously studied for decades, relatively few studies have addressed these colloidal structures. In this presentation, I will present our insights on the colloidal structures present in our daily coffee. We combined imaging, scattering, and rheological techniques to unravel the size, structure, and interactions of espresso colloids. We find extracted oil droplets, mostly in the submicron range, stabilized by protein-polysaccharide complexes at their interface, and relatively long fiber-like polymer structures. The size of extracted oil droplets gradually decreases as a function of extraction time, and the first fraction shows clear evidence for unfolded polymers in its scattering profile. The rheological characterization of espresso revealed that the first milliliters of espresso exhibit a considerable shear viscosity and even viscoelasticity, while later fractions have negligible viscosity. Combined, our results show that the size and structure of extracted lipids and polymers strongly depend on the extraction time. Mostly the first 6-ml fraction (of a 18 mL espresso) contributes to the 'body' of espresso due to its highest concentration of dispersed colloids and the early extraction of unfolded polymers.

Keywords:
Coffee, Emulsions, Polymers, SAXS, Rheology

References:

Bertsch P, Subramaniyan A, Yeretzian C, Salentinig S. The Nano World of Espresso: Oil Droplets and Rigid Polymer Structures Shape the Shot. ChemRxiv. 2025; doi:10.26434/chemrxiv-2025-r0nrj

Acknowledgements:
The Swiss National Science Foundation funded this work through project No. 186251 and the National Center of Competences in Research (NCCR) Bioinspired Materials

Water in Water emulsions stabilized by cruciferin-based microgels and microcapsules

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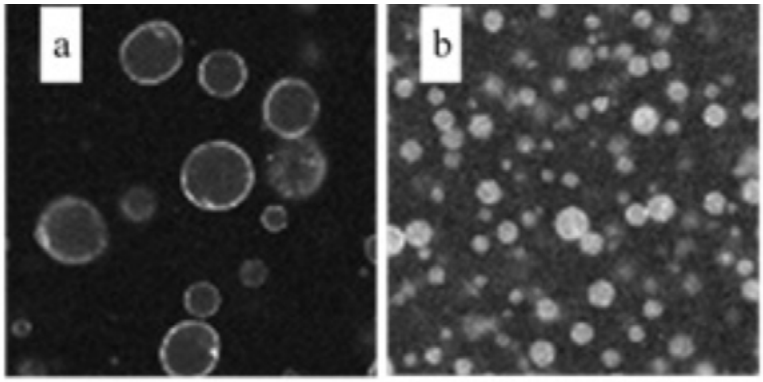
Rapeseed is mainly used for oil extraction, with the remaining material often discarded or used as animal feed. However, it contains 30% to 45% high-quality protein, primarily composed of cruciferin and napin. While napin was found to be heat-stable, cruciferin can remarkably form stable suspensions of well-defined microgels (CMG) upon heating at 80°C for only 5 min [1]. The diameter of the microgels can be varied between 0.1 and 0.4 µm depending on the pH. We will show that CMG are efficient emulsifiers for water-in-water (W/W) emulsions and that they spontaneously crosslink (a phenomenon that can be fasten upon heating) at the interface to form stable microcapsules (MC) whose size can be tuned upon modifying the proportion of each phase in the W/W emulsions or upon modifying the concentration of MC [2]. These microcapsules can, in their turn, be used to stabilize W/W emulsions. The microstructure of W/W emulsions stabilized by MC appeared to depend on the compatibility of the polymer within the MC with those in the dispersed and continuous phase. Depending on the compatibility, the MC form a layer at the interface that protrudes inward to the droplet phase or outwards to the continuous phase resulting into raspberry-like structure in the former case or into a network of connected droplets in the latter one.



Confocal microscopy images (40 × 40 µm) of a W/W emulsion containing (a) 3 g/L, (b) 14g/L cruciferin MG. The protein microgels were fluorescently labelled.

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Acknowledgements:

This work was supported by the Novo Nordisk Foundation, grant number NNF21OC0065495.

Switchable foam stability by Janus-like plant protein particles.

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Protein foams, in applications like a cappuccino, need to be sufficiently stable, whereas in large-scale production processes, such as protein extractions, stable foams are not desired. Therefore, in an ideal situation, the foam stability of proteins should be tuneable. We found that proteins from rapeseeds, known as napins, have a unique Janus-like amphiphilic particle structure with a diameter of 5 nm, which, when they are not charged, form stable foams similar to those of whey and egg proteins. However, a slight increase in their surface charge (-15 mV) through a pH change resulted in a rapid foam collapse. Through ellipsometry and atomic force microscopy, it was revealed that napins, when they are not charged, form dense, superhydrophobic viscoelastic monolayers on the surface. Increasing their charge to -15 mV enhanced the repulsion between protein particles and altered their interfacial arrangement to a less dense monolayer, resulting in a more liquid-like surface structure. Using the thin film balance, we found that the pressure at which the bubbles coalesce is twice as high when the napins have no surface charge in comparison to when the surface charge is at -15 mV. We demonstrated that the behaviour of napins as amphiphilic Janus-like particles is highly dependent on the repulsive electrostatic forces. This behaviour allows us to control the foam stability and enables a broad use of napins in foam-based applications and processes.

Keywords:
Foams, napins, interfacial rheology, thin film dynamics, Janus-like particles

Balancing oil and protein content: antifoam regimes of foamed protein-based emulsions

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The presence of liquid oil droplets in protein foams can reduce foaming functionality through antifoam activity. However, no systematic study on the regimes of antifoam activity at different protein and oil contents is currently available for foamed food emulsions. A (soy) protein solution that was nearly completely free from aggregates and an emulsion (sunflower oil) with controlled droplet size distribution were used. Mixing these [1].
Antifoam activity was drastic at low and moderate protein contents (<0.7 wt%) and was not observed at high protein contents (>1 wt%). Oil contents as low as 0.006 wt% caused notable foamability reductions. Remarkably, recovery of foamability functionality was observed at oil contents above 0.1 wt%, with full restoration of foamability functionality at high oil contents above 10 wt% (fig. 1.). The same regimes of antifoam activity as a function of protein and oil content were also observed for multiple other protein types besides the used soy (skim milk, egg white, and potato) and different oil types besides sunflower (rapeseed and corn) [1].
Only foamability, and not foam stability, was affected by the presence of oil droplets in whipped foams, indicating the dynamic nature of the antifoam effect [1]. In line with the low timescales typically associated with dynamic antifoams, a correlation between fast protein adsorption kinetics (rising bubble tensiometry) of certain protein types (milk) with reduced antifoam activity at relatively lower protein contents was observed. Furthermore, the role of a characteristic time for adsorption at the bubble air-water interface [2] was further substantiated in single bubble lifetime tests where longer bubble rise times (i.e. adsorption time) resulted in lower antifoam activity. Additionally, the relatively low antifoam activity for protein types (egg white) that form highly viscoelastic air-water interfaces highlights the unique role of protein viscoelasticity and electrostatic repulsion to prevent antifoam activity. This was further substantiated by observations of complete prevention of oil droplet entry at a protein-stabilized air-water interfaces at relatively low protein contents.
In conclusion, we have established generic trends as a function of protein and oil content. We have shown that the effect can occur at very low oil contents, which can make it an overlooked factor in protein foaming research. Our research highlight the drastic nature of antifoam activity, especially for plant-based protein systems. Finally, we provide first insights in the unique interfacial and capillary dynamics of antifoam activity for protein-stabilized foamed emulsions.

Keywords:
antifoam, emulsions, foams, protein, plant-based

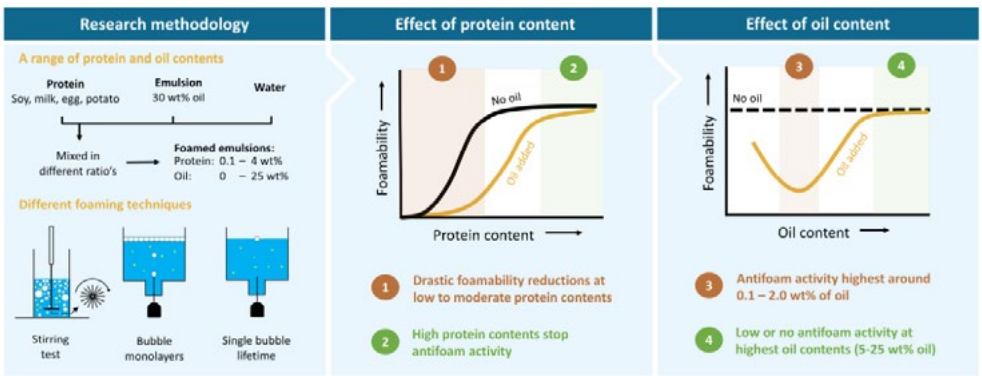

Figure 1: graphical abstract of used methods and results found in [1]

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Dynamic and equilibrium surface layer properties of jujube (Ziziphus jujube) leaf extract

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Many fluid systems in our modern world are based on stabilized foams and emulsions, in particular in the field of food technology. The increased attention to sustainable stabilizers leads to a continuously increasing interest in biosurfactants, such as saponins extracted from various natural sources [1]. This work deals with jujube leave extract, one of the many possible sources for saponins. The optimum application of biosurfactants requires basic knowledge about their adsorption behavior at relevant interfaces, such as water/air or water/oil for applications in foams or emulsions, respectively. We studied the adsorption dynamics, the dilational visco-elasticity and the equilibrium surface layer behavior of saponins extracted from jujube leaves by drop profile analysis tensiometry (PAT1, SINTERFACE Technologies, Berlin). Due to the high surface activity, similar to other saponins [2], this biosurfactant adsorbs remarkably already at rather low concentrations so that the formation of the surface layers is rather slow. Hence, the determination of the dynamic and equilibrium adsorption layer behavior requires particular measuring procedures. In this study, we prepared 10 concentrations of jujube leaf extract powder (3 mg/l to 700 mg/l) and investigated their elastic modulus and surface tension. An adsorption-desorption protocol based on a square pulse perturbation of the solution drop surface area is applied to determine the equilibrium surface behavior in the most reliable way. The surface equation of state shows highest surface pressure values Π of more than 17 mN/m, while the values of the dilational surface elastic modulus $E = -d\Pi/d \ln A$ increase up to 120 mN/m, respectively. The protocol for the adsorption layer formation included a compression and expansion step of the solution drop surface area A to determine the equilibrium surface behavior in a most reliable way.

Keywords:
Saponin extract, adsorption kinetics, surface equation of state, dilational surface viscoelasticity, drop profile analysis tensiometry

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Botanical Extracts in Water-in-Oil Emulsions: A Natural Strategy to Enhance Sunflower Oil Oxidative Stability

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Natural compounds are well known for their strong antioxidant properties; however, their hydrophilic nature limits their direct application in fats and oils, where oxidative degradation is a major concern. To overcome this problem, water-in-oil emulsions offer a promising strategy, improving the dispersion of these bioactive compounds in lipid environments but also enhancing their ability to inhibit oxidative processes at the oil-in-water interface, where oxidation generally starts. This study evaluated a plant-based extract to improve the oxidative stability of sunflower oil during a 2 weeks storage period at 45°C. The extract (0.06%) was firstly solubilized in 0.6% of water and then incorporated into the oil, and it was compared with BHT (0.02%), in accordance with the permitted level in edible oils, and with synthetic α-tocopherol (0.6%). Emulsions were preprared by mixing oil, 0.6% water and 1% polyglycerol polyricinoleate (PGPR) emulsifier. Antioxidant efficacy was assessed by monitoring the peroxide value (PV), conjugated dienes/trienes formation, and Rancimat stability; while physical stability was examined by evaluating changing in particle size distribution and turbiscan analysis. Regarding lipid oxidation, both the natural extract and BHT effectively counteracted oxidation compared to the control, whereas tochoperol exhibited a proooxidant effect. Indeed, at the end of the 14 days of storage, the peroxide value of the control reached 13.88 ± 0.09 meq O_2/kg, while BHT and the extract limited it to 7.18 and 8.28 meq O_2/kg, corresponding to a reduction of hydroperoxides by 48% and 40%, rescpectively ($p < 0.001$). Tocopherol, in contrast, showed a 13% increase of PV. Similar trends were observed for conjugated dienes and trienes, where BHT and the natural extract significantly delayed their formation ($p < 0.001$). Rancimat analysis confirmed these findings, as samples enriched with BHT and the natural extract desplayed significantly higher induction time ($p < 0.05$), confirming greater oxidative stability compared to the control. Regarding the physical stability, no significant differences in droplet size where observed between samples. Additionally, according to the Turbiscan Stability Index (TSI), all emulsions resulted stable during the first week of storage, showing only minor and reversible phase separation under thermal stress. However, during the second week, all samples lost stability, with the disappearing of the characteristic water-in-oil emulsion opalescence and the systems appearance of a transparent oil phase. Overall, the obtained results suggest that also hydrophilic extracts present a promising natural alternative to synthetic antioxidants for enhancing oil quality and reducing lipid oxidation, however a deeper investigation on the stability of the system has to carried out.

Keywords:
Natural Extracts, Oxidative Stability, Water-In-Oil Emulsions

Carrageenan Gels Formed Through Crosslinking with Rapeseed Proteins: Role of Electrostatic and Hydrogen-Bonding Interactions

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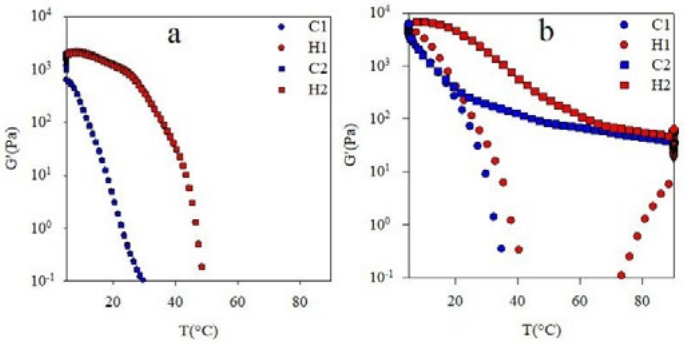
Rapeseed proteins, primarily cruciferin and napin, have attracted attention as sustainable alternatives to animal-derived proteins. We investigated the structure and rheology of aqueous mixtures of κ-carrageenan (κ-car) with cationic napin (nap), anionic cruciferin (cru), and rapeseed protein isolate (RPI), containing both proteins in equal proportions. Mixtures of κ-car with rapeseed proteins formed thermoreversible gels upon cooling, stabilized mainly by hydrogen bonding, without the characteristic coil-to-helix transition of κ-car [1]. Under these conditions, neither κ-car nor the proteins alone formed gels. At higher napin or RPI concentrations, gel formation was hindered by the formation of dense spherical domains arising from electrostatic complexation, which could be prevented by adding salt or increasing the pH toward the proteins' isoelectric point.
Upon heating to 90 °C, κ-car/cru and κ-car/RPI mixtures formed irreversible gels due to protein gelation [2]. Rheological measurements showed that the irreversible protein networks formed at high temperature were further reinforced during cooling by κ-car gelation. The extent of this reinforcement depended strongly on the relative binding affinity between κ-car and the proteins. In contrast, κ-car/nap systems did not gel upon heating but exhibited spherical domains due to coacervation at low napin concentrations (< 5 wt%) that aggregated and sedimented at higher concentrations.
The effects of pH, ionic strength, and component ratios on viscoelastic properties and microstructure before and after heating will be discussed. These results provide new insights into the interplay between coacervation due to complexation and gelation in κ-car–rapeseed protein systems, offering strategies for tailoring plant-based gel textures.

Keywords:
κ-carrageenan, rapeseed proteins, electrostatic complexation, hydrogen bonding, protein gelation



Evolution of G' as a function of temperature for κ-car/napin (a) and κ-car/RPI (b) mixtures during different cooling (C1 and C2) and heating cycles (H1 and H2).

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Structuring starch–protein systems from pea dry fractionation side streams for sustainable food applications

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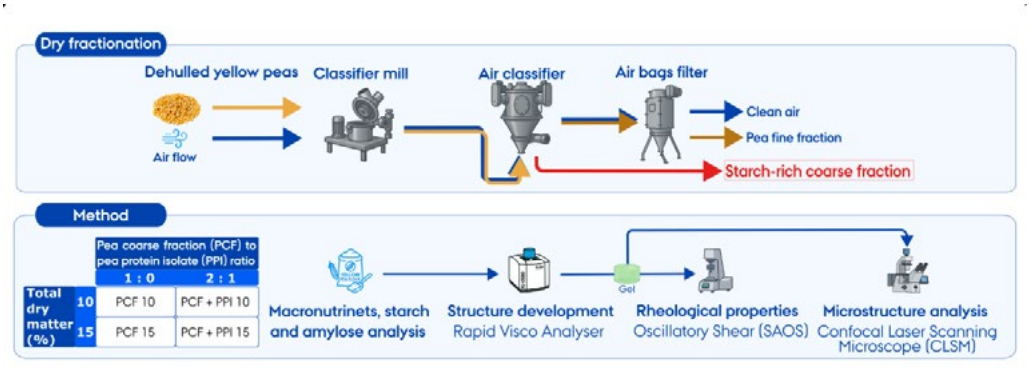
Dry fractionation of legume flours generates a high volume of starch-rich co-products, which remain underutilized despite their promising functional properties. Unlocking their potential as a structuring agent represents an opportunity to fully valorize all components of the legumes and foster a more circular and sustainable value chain. In this study, the colloidal properties of the starch-rich fraction from pea were investigated, exploring its multi-functionality when mixed with plant proteins.
The fraction was characterized for its macronutrient composition and starch properties. Gels were prepared at two dry matter levels (10% and 15%) with and without the addition of pea protein isolate (PPI). Structural development was monitored through Rapid Visco Analysis during thermal treatment, while the viscoelastic properties of the resulting gels were evaluated using oscillatory rheology (SAOS). Confocal Laser Scanning Microscopy (CLSM) provided complementary insight into the microstructural organization at the colloidal scale.
RVA analysis showed that at higher DM, the values of peak, trough, breakdown, final viscosity, and setback were higher for both formulations. Interestingly, the addition of PPI had the opposite effect at 10 and 15% DM. In the first case, it determined lower values for all the RVA parameters, whereas in the second case, the values increased with higher protein content. SAOS measurements showed, as expected, higher elastic (G') and viscous (G") moduli at higher DM. Meanwhile, the addition of PPI had a weakening effect on the gel structure. Under these conditions, the samples at 10% DM containing only the coarse fraction exhibited similar textural characteristics to those at 15% DM with added PPI. CLSM imaging showed different starch-protein structures in each sample. Higher DM resulted in greater rupture of the starch granules, leading to the formation of a stronger network upon starch retrogradation. At the same time, the proteins present in the coarse fraction and those added with PPI interrupted the network, weakening the structure.
This work highlights the ability of minimally processed, plant-based co-products to act as functional structuring elements in colloidal systems, offering new routes for designing clean-label and sustainable food matrices. The findings demonstrate how controlling the balance between polysaccharide-rich fractions and proteins can be used strategically to engineer desirable textural properties, contributing to more resource-efficient food innovation.

Keywords:
Dry fractionation; Pea side streams; Structure design; Starch–protein systems; Rheology and microstructure



Overview of the dry fractionation process and experimental workflow

Blend or not to blend? Functional and Colloidal Properties of Yeast–Pea Protein Mixtures

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Alternative protein sources are needed to meet the growing global population and food protein consumption. However, protein extracted from legumes or microbes often lacks the techno-functional and nutritional properties of animal proteins when used alone. A promising approach to overcome these limitations is blending protein with different sources (1–2). However, the interactions among these ingredients remain poorly understood and require further investigation. The aim of this research is to investigate the techno-functional properties of yeast (YP) and pea (PP) proteins blended in different proportions. Solubility of protein suspensions resulted in low values for both proteins, ranging from 4.33% for pure YP (YP_{100})to 30% for pure PP (PP_{100}). When the two proteins were blended, solubility increased to 10%, 17%, and 22% for the formulations with YP:PP ratios of 75:25, 50:50, and 25:75, respectively. In the emulsion systems, YP_{100} exhibited large oil particles with a $D_{4;3}$ of 20.44 μm and a span of 2.85, whereas PP_{100} emulsion showed a $D_{4;3}$ of 0.96 μm and a span of 1.83. In the blended formulations, YP_{25}:PP_{75} reached the highest value of 63.81 μm, while lower intermediate values were observed in the other blends that did not differ significantly from each other ($p > 0.05$). This behavior suggests an antagonistic interaction between YP and PP, leading to a poorly stable emulsion, mainly due to flocculation phenomena. The foaming properties showed that YP_{100} has lower foaming capacity (FC) than PP_{100}, with an FC of 14% and 169%, respectively. In the blends, FC increased to 30%, 76% and 126% as PP increased. The YP:PP blend seemed to have a synergistic effect on the Foam stability (FS) for the formulation YP_{75}:PP_{25}, with a value of 24%. The gelation kinetics showed a decreasing trend in the G' at the end of the cooling phase ($G'_{20°C}$) with values of 33.77 Pa for YP and 2170.34 Pa for PP. $G'_{20°C}$ increased in YP_{75}:PP_{25}, YP_{50}:PP_{50} and YP_{25}:PP_{75} gels with values of 35.58 Pa, 260.95 Pa, and 861.66 Pa, respectively, thus demonstrating a sinergystic effect between the YP and PP of PP. $G'_{20°C}/G'_{95°C}$ was used to investigate the main bounds participating in gelation process (5). The protein network was mainly formed by disulphide and hydrophobic interactions for YP alone with a value of 3.59, while in PP hydrogen bonds and electrostatic interactions were mainly contributing to the gel strength, with a value of 13.05 (5–8). $G'_{20°C}/G'_{95°C}$ decreased to 0.82 and 2.11 for the YP_{75}:PP_{25} and YP_{50}:PP_{50} gels respectively, while increased to 16.29 for the YP_{25}:PP_{75} formulation. This behavior might be attributed to new intermolecular interactions occurring during co-gelation that alter the protein network. Large Amplitude Oscillatory Shear analysis (LAOS) at a strain amplitude (y_0) of 1% showed that all the samples had a thin, elliptical elastic curves. As y_0 reaches 10% all the gels, with the only exception of YP_{25}:PP_{75}, showed an expansion of the area within the curve and a deviation of G' from the linearity, indicating a reduction in the gel's energy storage capacity. Upon increasing y_0 to 63%, all the gels, with the only exception of YP_{75}:PP_{25}, exhibited rhomboidal curves, indicating a reduction in the gel's strength and a transition from elastic to viscous behaviour. YP_{75}:PP_{25} gel reported a rectangular shape curve, indicating the almost complete disruption of the structure. Indeed, YP_{25}:PP_{75} gel showed a shift toward rhomboidal curve and increase in the enclosed area at higher strain with respect to PP_{100} gel. These results indicate that multiple synergistic and antagonistic interaction mechanisms occur among proteins in blends, strongly influencing the techno-functional properties of each component. Understanding the functional properties of each individual ingredient, and how these change when combined at different ratios, is crucial for selecting the optimal formulation for the desired model system.

Keywords:
Alternative proteins, Plant proteins, Protein blends, Functional properties

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Faba Bean as a Promising Emulsifying and Gelling Alternative to Soy

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For several years, consumer demand has been increasing for minimally processed foods with a lower environmental impact and free from artificial chemical ingredients [1]. One potential solution to this challenge is the use of plant proteins, known for their stabilizing and gelling properties [2]. However, the complexity of these systems makes them difficult to control and remains a major barrier to their integration into food formulations.
Among the protein-rich plants, soy is the most extensively studied. Its good water solubility, along with its emulsifying and gelling properties, makes it an attractive candidate for use in the food industry. However, its high content of isoflavones, classified as endocrine disruptors, poses a risk with excessive consumption [3]. Although less studied, the faba bean shows a great potential. It can be cultivated in many regions of the world, including China, European countries, Australia and Ethiopia, and its tolerance towards cold climate enables local production while reducing environmental impact. Moreover, it offers valuable nutritional benefits that contribute to a healthy diet [4]. Despite being underappreciated, its physicochemical properties make it a highly promising candidate for innovative food applications.
The objective of this project is to understand the emulsifying and gelling properties of plant-based proteins and to relate them to their composition, their production process, and their physico-chemical environment in simple systems. The ultimate goal is to apply this knowledge to more complex systems, such as dairy-like food models. Faba bean protein isolate and soy protein isolate with equivalent protein contents were studied. Although both are capable of forming stable and well-structured emulsions and gels, their levels of water-soluble proteins differ. Soy protein isolate, which contains a higher proportion of soluble proteins, appears to be mainly stabilized by this soluble phase. In contrast, faba bean protein isolate seems to be stabilized by both the soluble and insoluble fractions in a more balanced way. The gelation mechanism also appears to be influenced by the relative contributions of the soluble and insoluble fractions. To investigate this, particular attention was paid to the roles of these two fractions. The solubility of the isolates in water was analyzed, along with the ability of the different plant protein fractions to reduce interfacial tension and form stable emulsions. The gelling ability and mechanism were further examined through rheological measurements.

Keywords:
Emulsion, Faba bean, Gel, Lipids, Proteins, Soy

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Enzymatic engineering of plant-based dietary fibre hydrogels from agricultural side streams

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Dietary fibre intake in Western societies does not reach the recommended nutritional guidelines, due to the prevalence of refined ingredients in our food products. This is commonly referred to as "the fibre gap", which is partially responsible for the large occurrence of metabolic diseases in our societies. On the other hand, agricultural side streams and food waste constitute a huge environmental burden, accounting for 8 to 10% of the total greenhouse gas emissions. Such agricultural side streams are precisely rich in cell wall dietary fibres, that end up discarded due to their insoluble nature and poor organoleptic properties. However, cell wall dietary fibres have huge potential for the development of new food ingredients and materials with innovative functional properties and health benefits. One of the challenges for the upcycling of agricultural side streams is their heterogeneous composition and insoluble structure, which hinders the development of effective processing technologies.
In this presentation we will discuss some of the challenges and opportunities that green chemistry and biotechnology provide for the upcycling of agricultural side streams into functional and healthy plant-based dietary fibre ingredients. We have developed processes using subcritical water for the extraction of complex dietary fibres from insoluble side streams from cereal [1,2] and fruit [3] processing. Controlling the extraction conditions (ie temperature, pH, time) enables to tune the molecular structure of the target dietary fibres in terms of molecular weight and degree of substitution [4,5] , preserving their bioactive (antioxidant) properties. The application of enzyme technology using specific hydrolase families based on substrate recognition affinity enables the production of prebiotic oligosaccharides with tailored molecular structures from insoluble and recalcitrant agrifood side streams. These specific oligosaccharide structures promote the growth of beneficial gut bacteria and the production of short chain fatty acids [6] . Moreover, functional dietary fibre hydrogels and emulsifiers can be produced using oxidative enzymes with radical scavenging activity. [7-9] The network structure of the hydrogels and their rheological properties can be further controlled by auxiliar hydrolytic enzymes [10] . This presentation highlights how development of integral biorefinery approaches for the maximised use of side streams is necessary for achieving a true circular food system.

Keywords:
Plant-based hydrogels, dietary fibres, antioxidant properties, enzyme technology, glycosyl hydrolases, oxidative enzymes, rheological properties

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Acknowledgements:
The authors acknowledge the Swedish Research Council Formas for the financial support to this work (Project 2020-01575) and to PLENTY – a Centre for Circular and Symbiotic Food Provisioning (2024-01152).

Formulation engineering of melt-in-the-mouth plant-based protein-rich gels

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This study aims to develop vegan gelatin analogue gels for patients with dysphagia who require melt-in-the-mouth meals with a soft texture. The goal is to produce a formulation that is both easy to swallow and nutritionally rich, particularly in protein content. A thermo-responsive soft gel system combining low-acyl gellan gum (LAG) and tamarind seed xyloglucan (TSX) was formulated to melt at in-mouth temperature. Differential scanning calorimetry (DSC) and rheological analyses indicated that LAG acts as the primary network-forming biopolymer, while TSX fills the pore spaces within the gel matrix, as confirmed by cryogenic scanning electron microscopy (Cryo-SEM). Depending on total polymer concentration and mixing ratio, TSX interacts with the LAG network, compromising the thermo-reversibility of the sol–gel transition. Thermo-reversibility is also affected by the level of incorporation of pea protein isolate (PPI). A maximum level of addition of ca. 5 wt% to maintain thermo-reversibility was established. The PPI used in this study was commercially sourced and, as commonly reported, exhibited limited solubility in aqueous media. Consequently, the final gel characteristics arose from the combined effects of both the dissolved protein fraction and, to a large extent, protein aggregates that could be seen microscopically. It is proposed that at sub-threshold levels of PPI incorporation, the protein aggregates occupied pore spaces within the LAG network, residing alongside the TSX. However, at concentrations above the threshold, the formation of the LAG network appeared to be disrupted, leading to a structural transition in which the overall gel properties became dominated by the characteristics of the PPI phase. To address challenges in accurately 3D printing the LAG-TSX-PPI system, the concentration of pea protein isolate (PPI) was stepwise increased (0–10%) and printability characterized using oscillatory temperature sweep tests. At 5 wt% PPI, the maximum level to maintain thermo-reversibility, samples with high shape fidelity could be printed; an example is illustrated in Figure 1. This formulation also fulfilled the melt-in-the-mouth and soft gel requirement and is thus a promising basis for the development of more complex vegan gelatin analogues for dysphagia patients. A nutritionally complete and tasty meal would also contain a lipid phase and taste or flavour additives.

Keywords:
Vegan gelatin analogue; Low acyl gellan gum; Tamarind seed xyloglucan; Pea protein isolate; Dysphagia; 3D food printing

Fig. 1. 3D printed gel cube from a mixture of low acyl gellan gum and tamarind seed gum containing 5 wt% pea protein isolate.

Acknowledgements:
TM acknowledges the Royal Thai Government for funding her PhD scholarship and Ludwig Schneider and team from the Centre for Electron Microscopy at the University of Birmingham for carrying out the SEM imaging.

Polysaccharide-based microgels serve as fat replacers in fermented dairy products

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Fermented dairy products, such as yogurt, are a staple in many diets worldwide and continue to attract consumer interest due to their nutritional value and versatility. In particular, the creamy texture of yogurt is a key attribute driving consumer preference. Growing awareness of healthy eating, including the desire to reduce fat intake, has sustained demand for low-fat products. However, consumer acceptance of these products is not always given, as fat reduction often leads to a loss of creaminess and, consequently, reduced enjoyment.

The addition of hydrocolloids is a common strategy to counteract the negative effects of fat reduction. However, when incorporated as soluble polymers, hydrocolloids often increase viscosity and gel strength, thereby enhancing firmness. In contrast, when polysaccharides are introduced in the form of microgel particles rather than as dissolved polymers, they can reduce viscosity and gel strength while simultaneously influencing the lubricating properties and creaminess perception of fermented protein gels [1,2].

In this study, we demonstrate that pectin-based microgel particles can serve as effective fat replacers in (high-protein) dairy yogurt. Different concentrations of pectin-based microgels were incorporated into milk with varying fat and protein contents prior to fermentation. The resulting yogurts were characterized rheologically and tribologically. The addition of microgels to reduced-fat yogurts yielded lubricating properties comparable to those of full-fat yogurts. Furthermore, the structure-reducing effect of microgels, previously observed in plant-based gels due to their function as inactive fillers, was confirmed for dairy systems. These findings are discussed in direct comparison with results from non-dairy matrices.

The study provides new insights into the interactions between fat, protein, and hydrocolloids in (high-protein) dairy systems and suggests formulation strategies to enhance creaminess and sensory appeal in yogurts while meeting evolving nutritional demands.

Keywords:
emulsions, gels, dairy, microgels, rheology, tribology

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Structuring Plant-Based Foods with Double-Network Emulsion Gels

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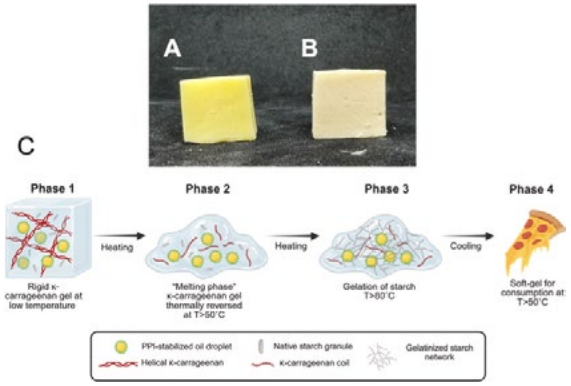
Designing plant-based foods that reproduce the temperature-dependent texture of dairy cheese and animal fat requires colloidal matrices whose mechanics can be "programmed" across cooking and eating temperatures. Here we present a double-network emulsion-gel paradigm that delivers such control and demonstrate it in two model systems: a cheese analogue and a fat analogue.
In the cheese analogue, a pea-protein–stabilized oil-in-water emulsion is structured by κ-carrageenan (thermoreversible) and glutinous rice flour starch (thermo-irreversible), producing a sequential gel–sol–gel response on heating/cooling that underpins meltability and post-cooking softness. Rheological data shows a marked drop in G′ between ~50–75 °C (κ-carrageenan helix-to-coil) followed by a rise on starch gelatinization, while CLSM and synchrotron-FTIR mapping resolve the transition from granular to swollen starch and the redistribution of macro-components. The gels exhibit ≥ ~88–93% weight retention after five freeze–thaw cycles and meltability improvements (e.g., +12–116%) over commercial plant-based cheeses, with melting behaviour closer to dairy mozzarella under pizza-baking conditions.
In the fat analogue, a curdlan–konjac glucomannan (KGM) double network is thermally set in two steps (50 °C → 85 °C) around pea-protein emulsified canola oil. The curdlan low-set gel immobilizes droplets early, while an irreversible high-set scaffold and the KGM network then reinforce structure, yielding cooking shrinkage (57 ± 5%) and springiness (0.42 ± 0.05) comparable to pork fat. There was < 15% oil/water loss over five freeze–thaw cycles, with controlled oil release during oven baking, while synchrotron-FTIR confirms protein–lipid interfacial localization and polysaccharide framework continuity.
These examples showcase double-network emulsion gels as a general strategy to tune thermal transitions, while coupling interfacial stabilization with network mechanics by pairing reversible and irreversible gelation agents and sequencing their activation. The strategy could improve the creation of clean-label, high-performance plant-based foods and other functional colloids.

Keywords:
double-network gels, emulsion gels, plant proteins, κ-carrageenan/starch, curdlan/KGM, rheology, synchrotron-FTIR



Photographs of Dairy Mozzarella and PPI-κC-GRF emulsion gel, with a schematic representation of changes in internal structure during heating for PPI-κC-GRF emulsion gel (Yiu et al, 2026, Food Hydrocolloids, 171, 111850)

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Enzymatic hydrolysis: An approach to improve the lubrication properties of plant proteins

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With the expanding scale of the plant-based market, plant proteins have been widely incorporated into various formulations. However, undesirable sensory attributes, particularly astringency, of plant proteins remain the major barrier to broader consumer acceptance. Astringency has been found strongly associated with high friction as measured in tribological experiments. Hence, we demonstrated a biochemical approach, *i.e.* enzymatic hydrolysis, to reduce the oral friction of plant protein dispersions. Friction of samples was measured using a Rheo-tribometer equipped with 3D printed biomimetic tongue-like surfaces. To investigate the role of bulk human saliva and salivary pellicle in plant protein lubrication, bovine submaxillary mucin (Mucin) was used, and an in- *vitro* model salivary pellicle was dynamically formed under tribological shear. Dynamic light scattering, contact angle measurements and rheological analysis were employed to examine physicochemical properties relevant to lubrication. Legumin-rich fraction (LR) from yea pea flour was extracted and hydrolysed to varying degrees of hydrolysis (%DH; 1-12%). We found that hydrolysis was effective in reducing protein boundary friction, which is at low sliding speed. Notably, a twofold decrease was observed for hydrolysates with 10 and 12% DH, which was likely due to smaller protein particle size and lower surface contact angle. Mixing protein samples with mucin, representing the bulk human salivary mucin, led to further friction reduction in hydrolysate with 12%DH. More interestingly, in the tribological model which involves dynamically formed mucin coating, the addition of parent plant proteins caused an immediate increase in friction, suggesting displacement of the pre-adsorbed mucin layer by LR. In contrast, hydrolysed samples maintained friction levels close to those of the mucin coating alone. These findings advanced the understanding of plant protein astringency and offered a feasible approach to formulating next-generation plant-based products with improved mouthfeel.

Keywords:
Plant proteins; Enzymatic hydrolysis; lubrication; astringency

From Fibre to Function: Cellulose Nanocrystals Extracted from Spent Coconut Fibres as Pickering Emulsion Stabilizers

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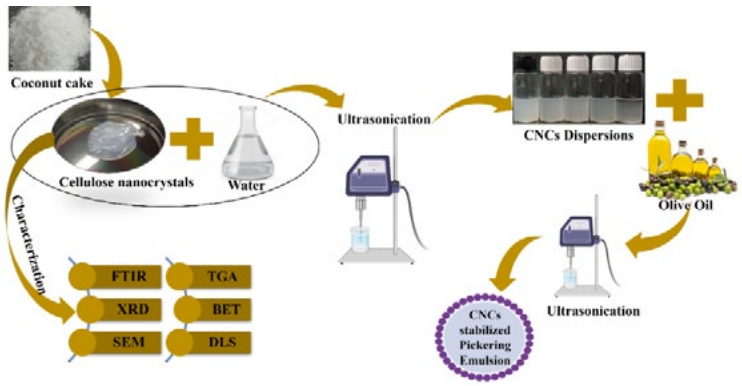
The sustainable production of food ingredients is receiving growing attention due to environmental concerns and the global push for circular economy practices. Spent coconut fibres (SCFs), by-product during virgin coconut oil production, contain considerable amount of cellulose, thereby the effective isolation of cellulose from them leads to value addition to coconut process industries. Cellulose in nano-sized forms, offers a novel green and sustainable technology for stabilizing emulsions, with significant applications in colloid and food soft matter. In the present study, SCFs were sequentially pretreated with alkali and bleaching processes to remove non-cellulosic components, yielding purified cellulose. After that, acid hydrolysis was carried out using 60% (w/w) sulfuric acid at 45 °C for 45 min, resulting in cellulose nanocrystals (CNCs) with a yield of 15.94 ± 0.62% (w/w). FTIR spectral analysis revealed that the functional groups of obtained cellulose and CNCs remained unchanged. The obtained CNCs exhibited a high crystallinity index (76.92%) with an average crystal size of 2.21 nm, enhanced surface area (4.74 m^2/g), good thermal stability (374 °C) and smaller hydrodynamic size (228.5 ± 8.03 nm). The Zeta potential of 0.5% (w/v) CNCs suspension was −47.7 ± 1.00 mV, indicating strong repulsive interactions among the nanocrystals. The water holding capacity (9.94 ± 0.06 g/g), oil holding capacity (10.88 ± 0.55 g/g) and swelling index (14.20 ± 1.2 ml/g) of CNCs demonstrated the unique interaction with both water and oil, defining its amphiphilic nature. The extracted CNCs from SCFs were evaluated at concentration range of 0.1 to 2% w/w, to formulate stable olive oil-in-water (O/W) Pickering emulsions (PEs). All PEs formulated in this study exhibited zeta potential greater than −30 mV, indicating good electrostatic stability. PEs containing 1% and 2% CNCs concentration showed dense three-dimensional gel networks enhancing emulsion stability over a 36-day storage. In conclusion, this study demonstrated the valorisation of SCF for CNC production, contributing to sustainable development and offering a natural, biocompatible stabilizer for O/W Pickering emulsions.

Keywords:
Spent coconut Fibres, valorisation, Cellulose nanocrystals, natural stabilizer, Pickering emulsion, Droplet Size, zeta potential



From spent coconut fiber waste to functional CNCs for Pickering Emulsions

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Acknowledgements:
N Sai Prasanna is thankful for the support provided by the Department of Science and Technology – Science and Engineering Research Board, Govt. of India, Confederation of Indian Industry (CII) under “Prime Minister’s Fellowship for Doctoral Research” scheme. The authors would also like to thank the Department of Chemical Engineering, IIT Tirupati for providing various characterization facilities.

Combined enzymatic pre-treatment and microfluidization allow production of stable low-viscous suspensions of high-cellulosic dietary fibre by-products

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Pea hull, a high cellulosic dietary fibre by-product, represents a promising ingredient for fibre enrichment of liquid foods. However, due to the dense, compact organisation of the cell wall, its application is limited by poor solubility and a grainy mouthfeel. Conventional strategies for upgrading high-cellulosic dietary fibres rely primarily on mechanical size reduction. This approach results in highly viscous suspensions, restricting their application in liquid matrices. Therefore, complementary pre-treatments capable of modulating fibre functionality are required.
This study aimed to produce low-viscosity, non-sedimenting pea hull suspensions by combining enzymatic hydrolysis and microfluidization, using a crossed mixture–process experimental design to elucidate the role of enzyme composition and hydrolysis time. To this end, the effects of hydrolysis time (30 to 240 min) and enzyme mixture composition (ternary mixtures of cellulase, xylanase, and a 1:1 combination of polygalacturonase and arabinanase) on particle size distribution, insoluble mass (IM), viscosity and physical stability were studied and modelled using a crossed mixture ternary model ($R^2 > 0.93$).
Hydrolysed–microfluidized suspensions produced with 50–75% cellulase and 20–45% xylanase exhibited marked reductions in insoluble mass and viscosity while maintaining physical stability, compared to solely microfluidized samples. Microstructural analysis revealed looser particle architectures and larger voids, indicating that partial enzymatic disruption of the cellulose–hemicellulose network governs pea hull functionality. Viscosity and sedimentation behaviour were primarily determined by insoluble mass concentration and particle-network formation, whereas the soluble fraction, mainly composed of low-molecular-weight carbohydrates, contributed minimally to viscosity. At comparable insoluble mass levels and similar particle sizes, differences in fibre microstructure resulted in distinct viscosity, highlighting the role of fibre architecture.
Overall, this work demonstrates that combining enzymatic pretreatments with microfluidization enables the tailored production of stable, low-viscosity pea hull suspensions, providing a robust strategy for the valorisation of cellulose-rich side streams in liquid food applications.

Acknowledgements:
This IGF Project 21616N of the FEI is supported via AiF within the programme for promoting the Industrial Collective Research (IGF) of the Federal Ministry of Economic Affairs and Climate Action (BMWK), based on a resolution of the German Parliament

Emulsifying Properties of White Chlorella Biomass and Its Fractions after Cell Disruption by High-Pressure Homogenization

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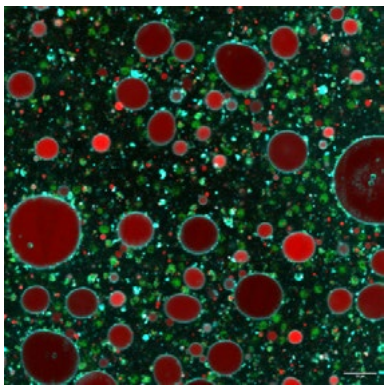
Microalgae have emerged as a promising source of nutritional, economical, and sustainable proteins. *Chlorella* stands out for its high content of proteins, vitamins, and minerals [1]. White chlorophyll-deficient allow wider use in food applications [2]. Microalgal biomass has mostly been incorporated into pre-stabilized emulsions to assess its influence on the overall system [3]. Studies on emulsifying capacity mainly focused on isolated proteins, whose extraction compromises native functionality [4]. However, the functional valorization of the whole biomass as an emulsifying ingredient, and the understanding of soluble and insoluble fraction in emulsion stability, remain limited.

This study investigated the emulsifying potential of white *Chlorella* biomass suspension, after High-pressure homogenization (HPH) disruption. Fractions (total, soluble and insoluble) were characterized for composition and particle size. Oil-in-water emulsions were formulated using either the whole total biomass (TB), the soluble (S) or the insoluble (I) fractions, to evaluate their individual stabilizing properties. A control emulsion was also formulated with hydrated and homogenized intact cells. Emulsion stability was monitored over 10 days and microstructure analysed by Confocal Laser Scanning Microscopy. Results were compared with a intact cells control emulsion.

Intact-cell suspensions formed emulsions, likely due to soluble compounds and cell overloading but showed rapid creaming, coalescence, and sedimentation. TB emulsions remained the most homogeneous system showing minimal destabilization (creaming or coalescence) and no visual sedimentation by day 10. TB and S emulsions initially exhibited similar droplet sizes (1–20 µm). S emulsion underwent rapid creaming and progressive coalescence from day 0 to 10. I emulsion displayed larger initial droplets (10–100 µm), similar to control, yet greater resistance to destabilization, suggesting steric and structural stabilization by cell debris. Microscopy revealed phospholipids adsorption at the oil–water interface and a loose network of particulate fragments around droplets, limiting aggregation.

Overall, disrupted biomass emulsions showed higher stability than those with intact cells, highlighting complementary roles of amphiphilic compounds and particles. The soluble fraction provides fast adsorption but weak strength, while the insoluble fraction offers steric stability without full coverage. Their combination yields the most stable emulsions. Future work will explore how HPH parameters influence disruption and macromolecule release to optimize emulsifying properties for sustainable food applications.

Keywords:
microalgae, biomass valorization, oil-in-water emulsion, cell disruption, high-pressure homogenization, microstructure



Confocal microscopy image of an emulsion formulated with the disrupted total biomass of white Chlorella, stained with specific markers (objective ×100; scale bar = 10 µm). Phospholipids are shown in blue, neutral lipids in red, and proteins in green.

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Pea protein hydrogels: influence of protein concentration, pH and ultrasound-assisted gelation

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Introduction

Increasing sustainability expectations have renewed interest in plant-based foods, but texture and formulation stability remain difficult to achieve. Plant-protein hydrogels are promising, although pea protein frequently forms weak or poorly structured gels [1]. In this research, a comprehensive characterization of pea-protein gelation, varying the concentration and pH was performed, followed by the application of HIU to improve the quality properties of the heat-induced gels.

Methods

Firstly, protein dispersions from pea protein isolate (86.1%) were prepared at varying concentration (5–17.5% *w/w*) and pH (pH 3 or pH 7). Protein dispersions were characterized in terms of flow behaviour using a rheometer (Discovery HR10, TA Instruments) and particle size (Mastersizer 3000, Malvern Instruments). Subsequently, hydrogels were prepared by heat-induced gelation and characterized in terms of structural, mechanical, and functional properties, including rheology, textural properties, water-holding capacity, and microstructure. Secondly, pea protein dispersions at pH 3 and at 10, 12.5, 15, and 17.5% (*w/w*) were prepared and treated with HIU (50% amplitude, pulsed mode, 4 min), and subsequent hydrogels were produced by heat-induced gelation. After HIU treatment, both protein dispersions and the subsequent hydrogels were characterized as previously described.

Results and discussion

Increasing the pea protein concentration enhanced the structural properties of the heat-induced hydrogels, as seen by an increased hardness, with values from 8.28 ± 0.39 g at a protein concentration of 5% (*w/w*) up to 579.75 ± 112.08 g at a concentration of 17.5% (*w/w*). In addition, self-standing pea protein hydrogels were only obtained at concentrations of 15% (w/w) or higher. These findings were in line with other structural properties of the hydrogels. An increase in the pea protein concentration formed hydrogels with higher water-holding capacity and increased complex modulus values (G*), indicating a more solid-like behaviour. This was also confirmed by confocal microscopy images, showing a more compact structure. With regard to the influence of pH, protein suspensions at pH 3 formed harder gels than at pH 7. For instance, at a fixed 17.5% (*w/w*) protein concentration, hydrogels formed at pH 3 had a hardness of 579.75 ± 112.08 g, while those formed at pH 7 had a hardness of 74.75 ± 18.74 g. Hence, these results evidence that protein concentration and pH are crucial factors determining hydrogel properties.

Regarding the suspensions, HIU treatment significantly ($p < 0.05$) reduced the particle size D[3,2] at concentrations from 10 to 15% (*w /w*), indicating aggregate disruption due to the cavitation effect. Furthermore, HIU increased the apparent viscosity in the shear range evaluated (0.01-1000 s^{-1}), which may suggest conformational changes in the protein structure.

With respect to the hydrogels, the HIU treatment lowered the minimum concentration of protein required to form a self-standing hydrogel to 12.5% (*w/w*). Both rheological tests, temperature ramp and frequency sweep, confirmed the formation of gels, where G′> G”, which indicates a more solid-like behaviour. Also, HIU treatment improved the mechanical and functional properties of the gels, as they increased in their hardness (up to 6.8-fold after HIU treatment) and water-holding capacity (up to 1.9-fold after HIU treatment). Microstructural analysis revealed more organized networks with smaller and more homogeneous aggregates.

Conclusions

Stronger gels can be formed at higher pea protein concentrations and at pH 3. In addition, HIU may be an effective strategy to reduce the concentration required for pea protein hydrogel formation and to improve their textural properties and homogeneity. Beyond the factors studied, this work advances the formulation of tailor-made hydrogels with specific mechanical and functional properties for diverse plant-based food applications.

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Acknowledgements:

This study was funded by the Ministry of Economy, Industry and Competitiveness (MINECO/FEDER, UE) throughout project PID2022-137838OB-I00. A. Bonilla acknowledges the scholarship PREP2022-000970 financed by MCIN/AEI/10.13039/501100011033 and FSE+.

Structural, Colloidal, and Functional Modifications of Coconut Protein Induced by Defatting: Roles of Solvent Polarity and Emerging Technologies

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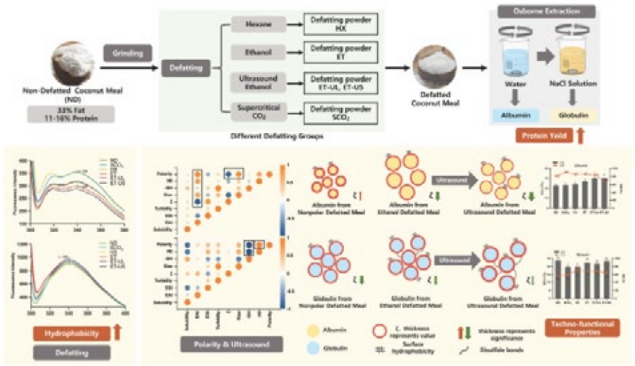
Defatting is a crucial pretreatment step in the extraction of plant proteins from food industry by-products. In this study, we evaluated the effects of several defatting methods (ethanol (EtOH), hexane (HX), supercritical fluid CO_2 (SCO_2), and high intensity ultrasound (HIUS) combined with EtOH) on the protein recovery, structure and colloidal properties of coconut albumin and globulin. The total protein extraction recovery increased from 36.4% in the non-defatted group (ND) to up to 39.2% after defatting, mainly driven by the higher globulin recovery (24.9% in ND to 28.4% with HIUS), whereas albumin recovery remained unchanged (11.4%) or slightly reduced under HIUS (10.8%). Defatting had minor effects on secondary and tertiary structures but markedly enhanced protein surface hydrophobicity. Globulin showed increased exposure of hydrophobic groups (204 a.u. in ND *versus* 222–274 a.u. in treated groups). In albumin, HIUS further amplified this effect compared with EtOH (58 *versus* 66 a.u.), leading to improved emulsifying capacity. A strong correlation ($|R| > 0.7$) was observed between solvent polarity and protein colloidal and functional properties of proteins. Defatting reduced globulin solubility (90% in ND *versus* 76–90% in treated groups), due to increased surface hydrophobicity. EtOH defatting enhanced the emulsifying properties of albumin compared with ND (26.8 *versus* 22.9 m^2/g). In globulin, however, HIUS promoted intermolecular disulfide bond formation, inducing aggregation and decreasing flexibility, which slightly impaired emulsifying performance. In contrast, SCO_2 caused minimal changes in functional properties, comparable to hexane and closest to ND. Distinct interfacial behaviors were observed across protein fractions and treatment groups. Globulin exhibited a higher diffusion rate ($k = 6.4 \times 10^{-3}$ in SCO_2 *versus* 4.3×10^{-3} in HIUS) compared with albumin ($k = 3.9 \times 10^{-3}$ in SCO_2 *versus* 2.5×10^{-3} in HIUS). SCO_2-treated proteins showed faster diffusion than those treated with HIUS. However, no significant differences were observed in the equilibrium interfacial tension at the tested concentration (0.1%). Overall, the use of SCO_2 and EtOH combined or not with emerging technologies presents a more environmentally friendly and promising alternative to conventional hexane-based defatting.

Keywords:
Coconut proteins, defatting, green extraction, interfacial properties



Overview on extraction, functional properties, and molecular state of albumin and globulin.

Impact of lipid co-isolation and processing strategies on the yield and foaming functionality of soybean okara protein isolates

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Soybean okara, the insoluble residue from soy drink and tofu production, represents a protein source that promotes circularity in the food system if effectively valorized. However, its valorization is hampered by a low protein extractability. To overcome this, processing strategies that allow efficient recovery of functional proteins are required. This study investigated particle size reduction, hexane defatting, and ultrasound-assisted protein isolation (extraction at pH 9.0, precipitation at pH 4.5), either alone or in combination, with the aim to improve the yield, purity, and foaming functionality of okara protein isolates. By comparing produced isolates with varying protein purity and lipid content, insights were gained into the role of co-isolated lipids in hampering the foamability of okara proteins.
Without using processing strategies, protein recovery from okara was less than 10%. An ultrasound-assisted process (2.5 W/mL for 5 min) produced isolates with a recovery of 35% and purity of 45 g/100 g DW (dry weight). However, these isolates exhibited a poor foamability of less than 20% at 5.0 mg protein/mL (pH 7.0). This was hypothesized to be due to the aggregated state of the proteins and/or lipid co-isolation. Therefore, okara particle size reduction by ball milling was applied to further improve the protein recovery and to increase the lipid removal efficiency. Indeed, the lipid removal efficiency of hexane defatting increased from 45% for non-ball-milled okara to 70% for ball-milled okara, likely due to disruption of cellular structures, as microscopically observed. Ball milling also improved the protein recovery using the ultrasound-assisted isolation process from 25% to 43% for defatted okara. Moreover, with or without hexane defatting, isolates from ball-milled okara differed in purity (75 g/100 g DW and 45 g/100 g DW, respectively), reflecting different extents of lipid co-isolation. Foamability at 5.0 mg protein/mL (pH 7.0) was more than 3-fold higher for higher-purity isolates compared to low-purity isolates (70% and <20%, respectively), while protein aggregation states in terms of non-covalent and disulfide bond mediated interactions remained largely similar. This indicates that lipid co-isolation, rather than protein aggregation, is the primary cause of the impaired foaming functionality of okara protein isolates, likely via anti-foaming effects. Foaming data were further supported by analysis of protein adsorption dynamics and dilatational rheology at the air-water interfaces.
In summary, our findings demonstrate that reducing lipid co-isolation enhances the purity and foaming performance of okara protein isolates. These insights are of great relevance for both academic and industrial applications. Future research should focus on unraveling the mechanisms by which co-isolated lipids destabilize protein-based foams.

Keywords:
soybean okara, soy protein, ball milling, defatting, ultrasound, lipid, protein aggregates, foam

Behavior, Functionality and Digestibility of a Protein Concentrate, and Integration of Oil Bodies into Skim Milk: A Dual Study of Products from Hempseed Water-Only Fractionation

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Hempseed (*Cannabis sativa* L.) is emerging as a sustainable source of high-quality proteins and polyunsaturated fatty acid–rich oils [1]. Mild processing techniques, such as water-only fractionation, offer an environmentally friendly alternative to conventional extraction methods, such as alkaline extraction of proteins or oil bodies. In this study, hempseeds were fractionated using a water-only process to obtain a hempseed protein concentrate (HPC) and an oil body–rich cream [2]. The properties and functionality of these fractions were subsequently investigated and compared with their alkaline-extracted counterparts.
The HPC, which contained 73.8% dry basis (d.b.) of proteins, was compared to a conventional hempseed protein isolate (HPI, 83.6% d.b. proteins), prepared through hexane defatting, alkaline extraction, and isoelectric precipitation. Physicochemical analyses, including particle size, ζ-potential, and thermal properties, revealed distinct differences between HPC and HPI, suggesting that the extraction method significantly affects protein behavior. This effect is likely influenced by the high phytate content retained in the water-only process, as phytate interacts with proteins and divalent cations to form insoluble ternary complexes. Functional properties of HPC were evaluated across different pH levels and heat treatments, demonstrating distinct solubility patterns and promising gelling capacity. In vitro protein digestibility assays (INFOGEST) revealed that all hempseed protein samples reached high digestibility levels at the end of the intestinal phase, comparable to reference animal-based proteins, such as whey protein isolate. Notably, despite its considerably higher phytate content, HPC demonstrated digestibility profiles similar to HPI, suggesting that phytate did not significantly impair overall protein breakdown under simulated gastrointestinal conditions.
Separately, the cream fraction (97.4% d.b. oil), composed mainly of oil bodies (OBs) and obtained through the same water-only fractionation, was compared to a conventional alkaline-extracted OBs fraction to assess compositional and colloidal differences. The results demonstrated that water-only fractionation effectively yields a highly purified OBs fraction with higher oil recovery (55.7% yield, compared to 45.7% for alkaline extracted OBs), offering a simpler and more sustainable alternative to alkaline extraction. Both OBs fractions were separately incorporated into skim milk systems to investigate their potential to replace cow milk fat globules. Their behavior and colloidal stability were assessed by particle size distribution, ζ-potential and creaming stability measurements. After high-pressure homogenization (50 MPa), oil droplets in the 0.01–1 μm range were formed (measured by static light scattering), exhibiting enhanced colloidal stability, likely supported by adsorption of milk proteins onto the droplet surface. Rheological analysis confirmed that both OBs fractions were able to form milk gels with similar mechanical properties to those of whole milk gels, highlighting their potential as functional fat replacers in dairy formulations.
In conclusion, this dual study demonstrates that water-only fractionation can produce both protein- and lipid-rich hempseed ingredients with distinct functional properties. HPC offers a minimally processed protein source with promising techno-functional and nutritional properties, while the OBs fraction show strong compatibility with dairy systems, supporting their use as clean-label fat replacers for hybrid products. These findings support the development of sustainable, low-impact processing strategies for plant-based food products.

Keywords:
Water-only fractionation, Mild processing, Hempseed, Oil bodies, phytate, Hempseed protein isolate

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Acknowledgements:
The authors thank the Chilean National Agency of Research and Development (ANID) for the doctoral studies financial support, through the Fellowship “Becas CHILE 2023” (Folio No. 72230349). Additional support was received from the Novo Nordisk Foundation (grant number NNF24OC0087818).

Phospholipids disrupt the interfacial network of proteins at the oil/water interface

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Oil/water interfaces are found in cosmetics, drug delivery, and food systems. These emulsion systems are often stabilized by proteins and/or low molecular weight emulsifiers such as phospholipids. Research questions about the interfacial structure of mixed interfaces, such as their composition and arrangement, as well as their interfacial rheology and dynamics, remain unanswered.
This study investigated the impact of charge and nature of phospholipid head groups on the interfacial structure, rheology and interfacial dynamics of protein-stabilized emulsions. A combination of conventional methods – such as drop tensiometry and interfacial rheology – and advanced methods – such as small angle neutron scattering and neutron spin echo spectroscopy – helps us to answer research questions about complex interfacial systems.
The head group of phospholipids strongly affects the interfacial structure and rheology of a β-lactoglobulin-stabilized emulsion. The interfacial structure was resolved using small-angle neutron scattering with partial structure factor analysis and coarse-grained modeling. The interfacial dynamics are characterized by 2D diffusion within the interfacial layer of the oil droplet and height fluctuations normal to the interfacial layer. The interfacial dynamics of the protein are inert for changes in interfacial structure, composition, and rheology, although structure and rheology have a strong influence on each other. These results provide guidance for the emulsion characteristics of food, cosmetics, and drug delivery systems (1,2).

Keywords:
Oil/water interfaces, scattering, phospholipids, β-lactoglobulin, emulsion

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Structure, Heat, and Time: The Dynamic Life of Protein–Phospholipid of Oil-Water Interfaces

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Phospholipids (PLs) and proteins such as β-lactoglobulin (β-LG) are key natural emulsifiers in food and pharmaceutical systems. PLs adsorb rapidly and form compact monolayers, whereas β-LG builds viscoelastic protein networks that provide long-term stability. When used together, their interfacial interactions depend strongly on the molecular structure of the PL and on processing conditions, leading to either co-adsorption or competitive displacement. Most studies focus on long-time interfacial behaviour, while in practice droplet formation and early stabilisation occur within milliseconds. To fully understand emulsion stability across time and processing, it is thus essential to bridge these regimes from rapid adsorption during emulsification to slower rearrangements and heat-induced transformations.

Here, we investigated β-LG combined with saturated (PC 18:0) or unsaturated (PC 18:1) phosphatidylcholines using complementary techniques that capture both equilibrium and dynamic behaviour. Interfacial rheology, ζ-potential, SAXS, μDSC, and CLSM were complemented by microfluidic droplet coalescence experiments probing adsorption and stabilisation at sub-second timescales across 20–90 °C.

On very short time scales (ms-s), combining β-LG with PLs markedly enhanced droplet stability compared to either component alone, revealing a clear synergistic effect against coalescence, most pronounced at elevated temperatures. Below 75 °C, saturated PC 18:0 promoted partial unfolding and co-assembly of β-LG at the interface, yielding cohesive and highly viscoelastic films and increased emulsion stability over time. In contrast, unsaturated PC 18:1 progressively displaced β-LG, leading to less elastic interfaces and reduced long-term emulsion stability. At higher temperatures, interfacial multilayer formation occurred irrespective of PL type, although β-LG retained more structure in the presence of the saturated PC 18:0.

These findings provide molecular-level insight into how interfacial organisation evolves across time and temperature scales, offering design principles for selecting emulsifier combinations and processing conditions to create heat-resilient emulsions.

Keywords:
Emulsion Stability, Mixed Interfaces, Phase transition, Displacement, Competitive Adsorption

Acknowledgements:
This IGF Project (01IF23169N) of the FEI is supported within the programme for promoting the Industrial Collective Research (IGF) of the Federal Ministry of Economic Affairs and Climate Action (BMWK), based on a resolution of the German Parliament.

Dynamics of pulse protein arrested states – an in situ giSAXS study

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Pulses and beans are important protein sources in the current protein transition, but much of the behavior of pulse proteins in food systems is still unknown. In particular in interface-dominated materials (emulsions, foams, etc), the nanoscopic behaviour of a protein – how they fold, stretch, and lock into place – governs whether a protein assembly ends up as a soft gel, a rigid glass, or something in between.
In our lab we have used high resolution AFM to reveal the intricate superstructures of pulse proteins on air-water interfaces. While the resulting structures are very insightful, they are ex situ and do not provide access to the dynamic mechanisms that give rise to them. In this work we combine high-resolution AFM with synchrotron grazing incidence small-angle X-ray scattering on a liquid interface. This experiment allows us to uniquely follow how protein superstructures are formed in situ during the adsorption and aging process.

Keywords:
Pulse proteins, SAXS, giSAXS, AFM, interfacial structure

Sustainable emulsions stabilized by cruciferin that forms dynamic interfacial architectures

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Plant based proteins pave the way to sustainable milk drinks and industrial emulsions in general. Cruciferin, a protein from rapeseed, has great potential as green emulsifier [1], but details about its structure and mobility at oil-water interfaces are largely unknown. These properties are studied using small-angle neutron and x-ray scattering, and neutron spin-echo spectroscopy. From the atomistic modeling of the scattering curves we deduct that trimeric conformations prevail the scene. The surface coverage is characterized well by the analysis of the small-angle scattering curves. Coarse-grained modeling reveals protein protrusions from the central core of the subunits ("arms") that are more compressed in the interfacial film compared to the aqueous dispersion. The interfacial mobility is only marginally lower than in solution, indicating the arms still transiently extend and preserve a network, for the first time revealing the mechanism how cruciferin forms highly elastic 2d gel-like oil-water interfaces, as observed in macroscopic rheology. The high interfacial mobility may help in self-repairing non-stabilized interfacial fractions, reducing coalescence. Thus, this study serves as showcase how scattering experiments reveal molecular understanding of proteins at oil-water interfaces, which can stimulate development of new plant-based emulsion products, and contribute to the global protein transition.

Keywords:
Protein, Emulsion, Small-angle scattering, Neutron spin-echo spectroscopy, Neutron scattering, Coarse grained structure, Dynamics, Rheology

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The influence of wax-based oleogelators on microstructure evolution, rheology and diffusion

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Oleogels are emerging as promising fat-structuring systems in plant-based meat analogues, offering improved texture and oil retention using healthy unsaturated oils. This study investigates rapeseed oil oleogels structured with 10% (w/w) of candelilla wax, beeswax, or rice bran wax, focusing on their microstructure, thermomechanical properties, viscoelastic properties and oil diffusion behaviour[1] . A novel combination of low-strain rheo-microscopy, rheology, differential scanning calorimetry (DSC), light microscopy (LM) and confocal laser scanning microscopy fluorescence recovery after photobleaching (CLSM-FRAP) was employed. The results showed that candelilla wax formed a dense, homogenous crystal network, beeswax produced needle-like aggregates, and rice bran wax exhibited mixed spherulitic and fine crystal structures. DSC and rheo-microscopy revealed distinct crystallization patterns, with rice bran wax showing two crystallization events. Oil diffusion analysis using CLSM-FRAP was performed in four different regions; in-between crystals, in crystals, in mixed regions with both crystals and oil, and at random locations. The CLSM-FRAP analysis demonstrated that candelilla wax significantly retarded oil diffusion across all regions, while rice bran wax allowed faster diffusion in crystal-rich areas, indicating looser packing. In addition, work on nanolevel has been performed using transmission electron microscopy (TEM) showing the microstructure of oleogels in plant-based meat analogues. These findings in this work highlight the critical role of wax type in designing oleogels with tailored structural and diffusion properties for food applications.

Keywords:
Oleogels, plant-based meat analogues, microstructure, diffusion, rheo-microscopy, thermomechanical properties

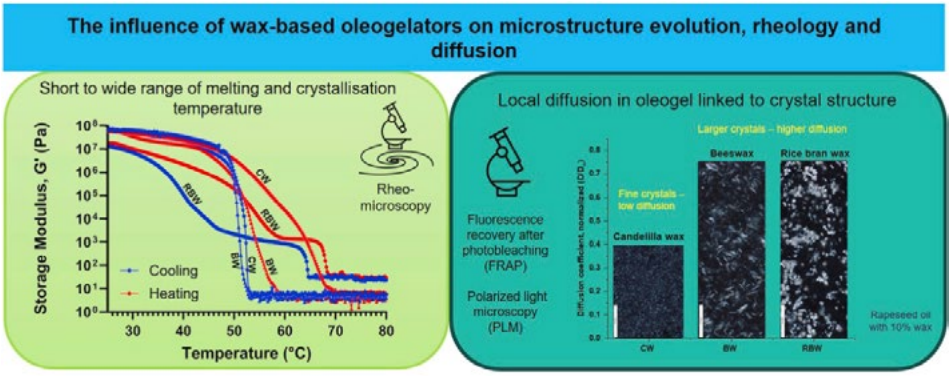

Illustration showing melting and crystallisation behaviour to the left and local diffusion linked to the microstructure to the right in the investigated oleogels

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Acknowledgements:
This work was supported by FORMAS, a Swedish Research Council for Sustainable Development [2022-01928].

Oleogelation using dried protein particles

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Solid fats, such as palm oil or butter, are important ingredients in food products, as they play an essential role in providing texture and mouthfeel. However, the use of such fats is not desired from a health and sustainability perspective. Liquid oils, extracted from easily accessible oilseeds, are preferred, but oils cannot be used as a structuring and texturising agent in foods due to their liquid nature. Over recent years, research has shown the possibility of structuring liquid oil with protein particles to gain solid properties, these systems are called protein oleogels [1]. Protein oleogels are promising substitutes for solid fats, but the current oleogelation methods, such as the emulsion-templated and solvent exchange method, are indirect and require multiple steps [2]. Depending on the method used, it is also difficult to control the specific properties of the oleogels, as the protein content and structure cannot always be controlled. A simpler and adaptable method is the use of dried protein particles that can be directly dispersed in oil to create protein oleogels. Such a direct method requires a well-flowing particulate powder with small protein particles. When particles are small, more surface area is available for protein-protein interactions, and a more efficient network formation can be obtained. In contrast, when particles are large, as in current protein powders, no 3D protein network can be formed to create a stable protein oleogel. In our work, we explore a novel drying method, aimed at altering the properties and flowability of the obtained dry protein powder. This drying method included different solvents with low polarity, such as isopropanol and hexane, aiming to reduce attractive forces between proteins during the drying process by adjusting the solvent wettability and accompanying capillary forces. We found that the drying solvent affected the protein size, since particle agglomeration was prevented by drying from apolar solvents. The dried protein particles were directly dispersed in oil, resulting in protein oleogels. The stability of the oleogels created using this direct-dispersion method depended not only on the size of the particles, but also on other properties that were influenced by the drying procedure. Using confocal microscopy and rheology, we show the microstructure and properties of oleogels and discuss how the network formed is affected by the drying solvents used. The use of the direct-dispersion method simplifies the process of oleogelation and provides potential to adjust the properties of protein oleogels.

Keywords:
Protein oleogel, oil structuring, protein drying, organic solvents, oscillatory rheology

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Structural modification of microbial exopolysaccharides and its impact on their functionality

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Exopolysaccharide (EPS)-forming lactic acid bacteria are commonly used for the production of fermented foods and significantly improve their texture and stability. These homo- or hetero-EPS show a high structural heterogeneity, which results in large differences in their macromolecular characteristics. Therefore, it is a major challenge to establish relationships between molecular structure and technofunctional properties. To overcome this drawback, the aim of this study was to produce structurally defined EPS that differ in only one structural feature (e.g. degree of branching, glycosidic linkages, molecular mass) and analyze for their functionality. For this purpose, microbially and enzymatically produced glucans with different backbone architectures were produced, isolated, and treated with branching sucrases to add side chains to specific positions with different degrees of branching. Furthermore, microbially produced hetero-EPS from *Streptococcus thermophilus* were isolated and treated with galactosidases to partially truncate or degrade side chains. The EPS were structurally characterized by NMR spectroscopy, methylation analysis, and enzymatic fingerprinting. Subsequently, all samples were analyzed for their intrinsic viscosity [η] with a rolling ball viscosimeter and size exclusion chromatography coupled with a refractive index and a viscosity detector (SEC-RI/IV). Previous studies showed that that [η] may serve as parameter in aqueous solution to predict the technofunctional potential of EPS (e.g. contribution to gel stiffness) [1].
The results indicate that [η] increases with a higher degree of branching for most of the dextrans, independent from the branching position (α-1,2,6 or α-1,3,6). Regarding the branching position, [η] was higher for α-1,3,6 branched dextrans than for α-1,2,6 and α-1,4,6 branched dextrans. However, the fine structure of the side chains has to be considered. With an increasing portion of α-1,3 or α-1,4 linkages in the backbone of the glucans, the molecules became more compact and [η] decreased. Hetero-EPS generally showed higher [η] than homo-EPS, and again higher [η] were observed with increasing degree of branching and a higher portion of dimeric compared to monomeric side chains.
Our findings contribute to the understanding of EPS functionality and allow for a targeted synthesis of polysaccharides with desired properties.

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Acknowledgements:

This work has been supported by Deutsche Forschungsgemeinschaft (DFG), project IDs: JA2033/3-1 | WE6416/4-1.

Multiscale Characterization of Interfacial Binding Between Soluble Amylose Chains and Waxy Corn Starch Granules

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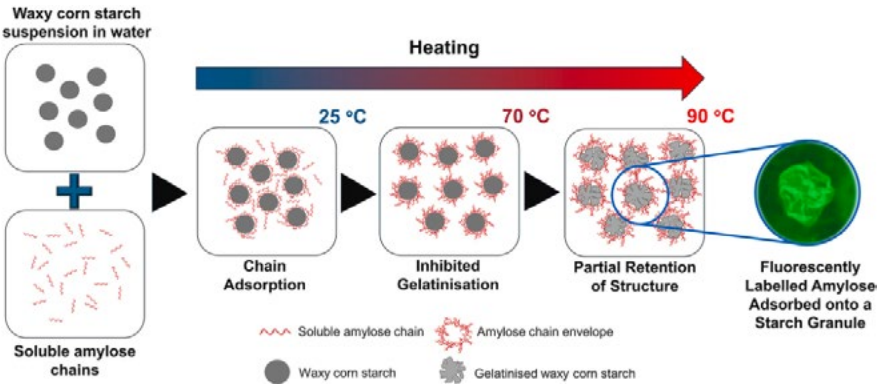
In this study, soluble amylose chains with varying degrees of polymerisation (DP 186–4020) were isolated via isoamylase debranching of amylopectin from native and waxy corn starches. When these soluble amylose chains are mixed with aqueous suspensions of waxy corn starch, spontaneous adsorption onto the surface of starch granules occurs. The resulting coating envelops the granules and markedly inhibits gelatinisation, increasing the onset temperature by up to 10 °C. Additionally, the amylose coating alters the pasting and short-term retrogradation properties of waxy corn starch, as evidenced by a reduction in trough viscosity, up to a 20 % decrease in breakdown viscosity, and approximately a 50 % increase in setback viscosity. This effect is both concentration- and DP-dependent. We found that chains with a critical length of 200 ≤ DP ≤ 700 produce the most pronounced effect and exhibit the strongest concentration dependence, suggesting that entropic considerations play a key role in starch–amylose interactions. Complementary analyses – including calorimetry, viscosity, turbidity measurements, and small-angle X-ray scattering – confirmed the inhibited gelatinisation and retrogradation. X-ray diffraction data further corroborated that the adsorbed amylose forms a hydrated, V-type-like polymorphic envelope. We hypothesise that this amylose coating restricts water ingress and inhibits granular gelatinisation, providing a physical basis for the observed inhibition. These findings highlight a previously undocumented role of soluble amylose chain length in directing starch thermal and structural transitions. Our results advance the fundamental understanding of starch–amylose interactions and offer a novel route for designing starch systems with enhanced functionality for applications in food processing and, more broadly, in (bio)material design.

Keywords:
Soluble amylose chains, Isoamylase, Small angle X-ray scattering, Adsorption, Interfacial supra-molecular assembly



Schematic illustration of soluble amylose chains adsorption on to waxy corn starch granule surfaces and the effect on the gelatinisation.

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Addressing multicomponent complexity in freeze structuring of food colloids

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Freeze structuring (FS) is a promising technique for engineering porous food structures through controlled ice crystal formation. FS's scalable, straightforward process enables precise control over pore morphology by manipulating ice crystal formation in suspensions through material and process parameters. However, food systems are inherently complex, heterogeneous, and polydisperse mixtures of polysaccharides, proteins, and fats. Unlike well-studied single-component systems, the interactions within multi-component mixtures during FS are challenging, limiting the broader adoption of FS for food systems (1).
In this work, we investigate how material parameters influence structural outcomes across scales, from microscale porosity to macroscale mechanical properties. We focus on solid loading and water–material interactions as key drivers of structure formation and propose viscosity as an accessible, potentially predictive parameter for morphology control. By enabling the direct structuring of complex food mixtures without pre-purification, we aim to position FS as a practical tool for efficient, nutritious, and scalable food design.

Keywords:
freeze structuring, food colloids, proteins, polysaccharides, rheology

Freeze structured variety of food products - from cream cheese to brocoli

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Inducing anisotropy in emulsion-filled hydrogels by unidirectional freezing

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Creating fibrous structures in hydrogels is relevant for developing plant-based analogues of meat and fish. A technique that allows to create fibers in a controlled way in hydrogels is freeze texturization. Freeze texturization enables anisotropic structure formation through unidirectional ice crystal growth, producing aligned fiber networks across micro- to millimetre scales. In this study, we systematically investigated the influence of initial gel microstructure and filler addition (liquid: linseed oil; solid: palm fat) on the structural and rheological properties of freeze-texturised hydrogels.
Potato protein gels (10–14% protein) were prepared at pH 6 and 7 (fine-stranded and particulate protein gels) and analyzed for Young's modulus (Ey), fracture strain (εf), fracture stress (σf), water-holding capacity, and mechanical anisotropy. Particulate gels (pH 6) were softer and more brittle, whereas fine-stranded gels (pH 7) showed higher stiffness. Freeze texturization decreased Ey, εf, and σf, but increased mechanical anisotropy, with fiber morphology dependent on protein concentration and initial gel type. Particulate gels formed coarser, larger fibers, while fine-stranded gels yielded finer, more continuous networks. Incorporation of oil or fat droplets increased gel stiffness, firmness, and fiber dimensions.
Overall, we demonstrated that modifying the properties of gels and incorporating fillers enables control over the structure and mechanics of hydrogels formed by freeze texturisation. By subtly varying the gel microstructure, significant differences in fiber morphology could be achieved. These results provide a toolbox that enables the creation of a wide range of fiber types in hydrogels, enhancing our understanding of hydrogel structuring and guiding the development of novel plant-based foods.

Keywords:
Protein gels, Fibres, Anisotropy, Freeze texturization, Texture

Edible films from cellulose microfibrils and solid fats

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Polysaccharide-based edible films are gaining attention as sustainable alternatives to synthetic packaging due to their biodegradability and mechanical strength, which arise from extensive hydrogen bonding and non-covalent interactions. However, their performance deteriorates under high relative humidity (RH), as water disrupts these interactions, leading to swelling and increased water vapor permeability (WVP) and oxygen permeability (OP) [1].
To overcome these limitations, hydrophobic fillers such as oils, waxes, and nanoparticles have been incorporated into film matrices. Oils effectively reduce WVP but are less effective against oxygen due to high oxygen solubility [2]. In contrast, solid lipids like waxes, particularly palm stearin, offer dual barrier functionality by impeding both water and oxygen diffusion [3]. The tortuous path theory explains how filler geometry and alignment influence permeability, with layered or elliptical particles providing superior barrier properties compared to spherical ones [4].
Recent studies have shown that molten lipids can self-organize with cellulose microfibrils (CMFs) into layered structures, enhancing barrier performance [5]. Upon cooling, waxes may retain this architecture, allowing microstructure control via thermal processing. Palm stearin, with a melting range of 40–62 °C, is especially promising due to its tunable mechanical and barrier properties [6].
Additionally, wax-containing films may enable encapsulation of oil-based pastes and offer heat-sealing capabilities, broadening their application in food packaging. These innovations align with current trends in sustainable and functional packaging solutions [7].

Keywords:
Polysaccharide films, edible packaging, permeability, wax fillers, palm stearin, microstructure

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Evaporation in bulk water, ethanol–water, and aroma–ethanol–water mixtures: interplay of geometry, composition, and interfacial processes

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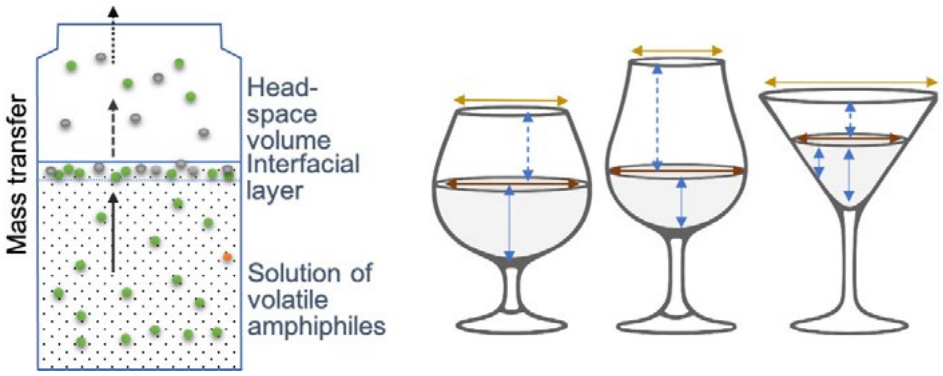
The evaporation of pure water and binary and ternary mixtures of ethanol and water containing aroma molecules will be discussed, with a focus on how composition and evaporation geometry influence evaporation dynamics and interfacial properties. Experiments were conducted in a controlled environment, employing gravimetric measurements and maximum bubble pressure tensiometry to track changes in weight, composition of the solution and surface tension over time. For pure water, the evaporation rate per unit area depends on the size of the exchange opening between the semi-closed headspace and open air. However, when normalised by liquid volume, this dependence on geometry is eliminated, indicating that gas-phase transport through the headspace is the rate-limiting step. In ethanol–water systems, the relative and absolute evaporation rates of the components are defined by alcohol concentration, surface-to-volume ratio, and liquid-phase diffusion path. Counterintuitively, for a 40 wt% ethanol solution, the largest evaporation area yields the highest absolute mass loss of ethanol; however, the greatest reduction in ethanol concentration occurs in the system with the smallest surface area [1]. Further results for ethanol solutions in the 5–80 wt% concentration range will be presented. In the ethanol–geraniol mixture, the surface tension remained nearly constant during evaporation, suggesting the presence of a persistent ethanol–geraniol interfacial layer that retards geraniol desorption [2]. We demonstrate that, in mixed solutions of volatile components, bulk-phase evaporation is governed by coupled gas-phase transport, liquid-phase diffusion, and interfacial kinetics, which are modulated by system geometry. These results pave the way for new approaches to studying beverages, where headspace volume and airflow set olfactory perception.

Keywords:
bulk-phase evaporation; ethanol–water mixtures; aroma compounds; diffusion-controlled evaporation; surface tension; mixed interfacial adsorption



Schematic representation of: (Left) co-adsorption in the interfacial layer and desorption into the gas phase of volatile amphiphiles in mixed aqueous solutions; (Right) examples of glasses for beverages. The lines indicate the geometric parameters, such as the diffusion paths, evaporation areas.

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Sustained Intestinal Release and Enhanced Bioaccessibility of Cinnamon Essential Oil from Cold Plasma-Modified Nanocarriers

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The increasing demand for natural food bioactives necessitates the development of clean-label and efficient carriers. In this study, a plant protein-polysaccharide complex was designed using pea protein isolate (PPI) and sodium alginate (AG) to encapsulate cinnamon essential oil (CEO). Cold plasma (CP) treatment was used as a non-thermal modification technique to enhance functionality. Different PPI:AG ratios (1:1 to 8:1) were tested, and the 3:1 ratio was found to be optimal based on particle size and polydispersity index (PDI). CP treatment (60 W for 4 min) significantly altered the surface properties and structure, as evidenced by SEM and FTIR, promoting higher encapsulation efficiency (EE) and water solubility compared to the untreated samples. The CEO-loaded PPI-AG nanoparticles exhibited improved physicochemical properties, including color, oxidative, and thermal stability. Structural alterations, such as increased β-sheet and β-turn content, support plasma-induced conformational changes. In vitro digestion using the INFOGEST model demonstrated a sustained release pattern of CEO with enhanced release during the intestinal phase from the CP-treated encapsulation systems, indicating improved bioaccessibility of encapsulated oil. The cytotoxicity and biocompatibility of the plasma-treated PPI-AG delivery system were evaluated using the MTT assay, which revealed that the treated delivery system maintained high cell viability, confirming its safety for food and nutraceutical applications. Overall, this study demonstrates that cold plasma serves as a green, non-thermal strategy for the functionalization of protein-hydrocolloid matrices for improved delivery of sensitive bioactives. This approach is promising for developing sustainable, stable, and functional food systems.

Keywords:

Cold plasma, Pea protein isolate, Sodium alginate, Cinnamon oil, Biopolymer encapsulation, Bioaccessibility, Cytocompatibility

Acknowledgements:

Ministry of Education and the Government of India for their funding support.
The German Academic Exchange Service (DAAD) provided funding and support through the Binationally Supervised Fellowship program (DAAD ID: 91897639).

Tailoring pea protein functionality via high-pressure homogenization for stabilizing and spray-drying hop-enriched O/W emulsions

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Hops are rich in bioactive secondary metabolites with techno-functional potential for food applications. However, their instability during processing and storage requires encapsulation strategies to preserve activity and facilitate their incorporation into formulations. Pea proteins represent a promising plant-based alternative to conventional encapsulating materials, consistent with current sustainability and clean-label trends. Nevertheless, their compact globular structure can limit their interfacial and encapsulation performance. High-pressure homogenization (HPH) has the potential to modulate pea protein structures, but its effect on encapsulation efficiency remains poorly explored.
The aim of the study was to understand how high-pressure homogenization (HPH), applied under different pressure–cycle combinations at constant energy density, can influence the colloidal and encapsulation properties of pea proteins. A hop CO_2 extract was characterized for its total phenolic content (TPC), antioxidant capacity (TEAC), and alfa- and beta- acids composition. Oil-in-water emulsions (20% w/w sunflower oil enriched with 3% w/w hop extract) were prepared with native or HPH-treated pea proteins (6% w/w, 15 MPa × 6 cycles; 22.5 MPa × 4 cycles; 45 MPa × 2 cycles; total equivalent energy applied 90 $MJ \cdot m^{-3}$) and maltodextrin, achieving a final oil-to-solids ratio of 1:3. Emulsions were analyzed for their droplet size distribution, viscosity and colloidal stability, while the resulting spray-dried powders were characterized for physical and chemical stability (e.g. SEM, tap and bulk density, encapsulation efficiency).
HPH significantly affected both structural and colloidal properties. FTIR spectra showed a reduction of lipid-related bands, while a broader O–H stretching band suggested enhanced hydrogen bonding within the matrix. The mean droplet diameter ($D_{[4,3]}$) decreased with HPH intensity. Although hop addition increased the flocculation index (FI%) for emulsion formulated with native proteins, HPH-treated samples, particularly at 22.5 MPa, exhibited reduced flocculation and enhanced emulsion stability, probably due to phenolic–protein interactions. These results demonstrate that, through an optimal pressure-cycle combination, HPH treatment of pea proteins enables their use as a promising wall material for the microencapsulation of hop bioactive compounds, supporting the design of a delivery system for lipophilic hop extracts and their functional compounds.

Keywords:
Pea proteins, high-pressure homogenization, wall material, microencapsulation, hop bioactive compounds

Interactive effects of polyphenols and artificial cell walls on starch transitions and starch and polyphenol bioaccesibility

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Starch, dietary fibre, and polyphenols are key components of plant-based foods whose coexistence in carbohydrate-rich matrices underpins both structure and nutrition. While increasing attention has been given to pairwise interactions among these components [1-3], their combined (three-way) interactions remain poorly understood and are rarely captured in real food systems or clinical studies [4]. At the core of these three-way interactions lies competitive binding. Fibre-phenolic and starch-phenolic associations compete with phenolic-enzyme binding, which underpins phenolics' inhibitory activity [5]. Conversely, phenolic–enzyme and starch-phenolic interactions compete with fibre-phenolic binding, potentially causing fibre aggregation and viscosity loss [6]. Similarly, starch-phenolic binding, which influences starch structure and digestibility, can shift under competition with fibre–phenolic interactions [7]. Understanding such complexity requires representative study models capable of reproducing both the chemical diversity of phenolics and the supramolecular architecture of plant cell walls. To this end, a controlled model system was developed using wheat starch, a bacterial cellulose analogue of the apple cell wall (aACW), and an apple pomace polyphenol extract, ensuring consistent starch-aACW-polyphenol ratios. Blends - starch + polyphenols (S-PP), starch + aACW (S-aACW), starch + aACW + polyphenols (S-aACW-PP), and starch + polyphenol-preloaded aACW [S-(aACW:PP)] - were subjected to simulated hydrothermal processing (RVA), storage, and *in vitro* digestion using the INFOGEST model with pooled human saliva. Results highlight the pivotal role of cell wall-polyphenol interactions in modulating starch and phenolic functionality in starch systems, with competitive binding as a key mechanism. Polyphenol retention by cell walls reduced their effects on starch swelling, retrogradation, and digestibility, while fibre-phenolic binding protected polyphenols from degradation but limited their intestinal release. Overall, this study provides critical insights into how the texture, stability, and metabolic impact of polyphenol-fortified, fibre-rich foods, such as fruit and vegetable pomace ingredients, depend on the interactions between polyphenols and cell wall structures.

Keywords:
Starch, Dietary fiber, Polyphenols, In vitro digestión, Component interactions, Competitive binding

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Dynamic colloidal transformations of human milk during infant in vitro digestion

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Human milk (HM) is a dynamic, naturally optimized colloidal system, in which the structural organization of lipids, proteins, and carbohydrates ensures efficient nutrient delivery to the infant. Over recent years, our research group has extensively investigated how variations in HM composition and microstructure influence its colloidal transformations during in vitro infant gastric digestion. These transformations determine the bioaccessibility and subsequent intestinal hydrolysis of nutrients. The studied variations reflected the impact of gestation length and lactation stage in colostrum and mature HM, and highlighted differences relative to cow's milk and selected commercial formulas.

A custom-made miniaturised semi-dynamic in vitro digestion model was developed and applied to mimic the physicochemical and enzymatic environment of the infant stomach. Such experiments remain a methodological challenge, given the complexity of the digestion processes and the limited availability of certain HM samples, particularly colostrum. The colloidal behaviour of HM emulsion systems during digestion was monitored by laser light scattering and laser diffraction combined with qualitative methods, enabling real-time observation of phase transitions, aggregation phenomena, and structural rearrangements within the complex digestion mixture. Gastric emptying was simulated through sequential sampling of digesta.

The digestion kinetics of HM were strongly governed by its evolving colloidal microstructure over a course of gastric hydrolysis. Under physiologically relevant acidification, the protein–lipid matrix underwent extensive rearrangements, dominated by fat droplet flocculation and coalescence, protein aggregation and gelation, and progressive enzymatic breakdown. These transitions led to pronounced phase separation, with creaming of lipid-rich fractions and sedimentation of protein aggregates. Such dynamic restructuring influenced the partitioning and release rates of macronutrients from the stomach, shaping their subsequent small intestinal hydrolysis.

Our findings reveal that the digestive fate of HM is fundamentally linked to its colloidal transformations under gastric conditions. Understanding these processes is crucial for designing infant formulas (IFs) that reliably reproduce the multiscale colloidal structure and digestive behaviour of HM. In this context, IFs should not be viewed merely as concentration-adjusted mixtures of selected HM components, e.g. macronutrients. Since they only constitute a subset of milk constituents, particular attention must also be paid to ensuring that the colloidal organization and interfacial dynamics in IF formulations closely resemble those of HM to achieve comparable structural and functional performance during digestion.

Keywords:
human milk, colloidal transformations, microstructure dynamics, in vitro digestion, infant model

References:

The project was financed by the National Science Center, Poland (grant no. 2022/47/I/NZ9/02749).

In vitro digestion of dairy milk and cream, and of their vegetal analogs

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Plant-based analogs are currently developed to mimic animal-based foods on the eve of the protein transition. Although their structural and textural characteristics are usually close to the original foods, their nutritional composition and quality are still not satisfactory. Notably, it is unclear how vegetal analogs to milk products behave in the human gastrointestinal tract, and how their nutrients are released. To address these questions, we conducted a study to compare the behaviors of commercial food emulsions, namely cow milk products and some soy-based analogs, in gastrointestinal conditions. Seven products were selected, of which the droplet size distribution and nutrient contents were characterized. One milk and one soy-based analog (both fortified with vitamin D) and one cream and one soy-based cream with close characteristics were then studied during in vitro gastrointestinal digestion. Oil droplet interactions were monitored throughout digestion using optical microscopy, laser diffraction analysis, and electrophoretic mobility. Lipid digestibility was quantified using HPLC-ELSD and pH-stat methods, and protein digestibility was quantified using the OPA spectrophotometric method. The intestinal bioacccessibility of lipolysis products and of vitamin D in bile micelles was measured using GC-FID and spectrophotometry, respectively. When comparing cow milk and soy-based products, despite having different compositions in fatty acids and amino acids, similar structural changes as well as similar lipolysis and proteolysis behaviors were observed during gastrointestinal digestion. Vitamin D stability and bioacccessibility were also close. These findings suggest that the main features controlling digestibility in these products are their physicochemical properties, including their physicochemical stability in gastrointestinal fluids.

Keywords:
emulsion, milk, cream, plant-based analog, digestion

Monitoring iron speciation during gastrointestinal digestion: X-ray Absorption Spectroscopy

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Iron is a micronutrient involved in critical metabolic processes, such as the oxygen and electron transportation, the cellular division and their differentiation and the energy metabolism, among others. However, the shift towards plant-based diets, coupled with sustainability issues in the food system, food insecurity, and the scarcity of affordable, sustainable sources of nutrition, has resulted in a lack of attention being given to micronutrient deficiencies. The World Health Organization (WHO) estimates that iron deficiency affects over 1.2 billion people worldwide and remains a global challenge to treat. Therefore, understanding the effect of digestion on iron at a molecular level is vital for developing effective, sustainable nutritional interventions.

This study investigated the impact of digestion on iron speciation in food. In this study, heme iron from myoglobin was selected as the 'gold standard' food source as it has been shown to be more easily absorbed than non-heme iron. All samples underwent an in vitro gastrointestinal digestion process in accordance with the standardised INFOGEST protocol. The effect of digestion on iron speciation was then monitored using advanced X-ray absorption spectroscopy (XAS).

Preliminary results confirm that heme iron maintains its state (XANES) during digestion. Additionally, EXAFS analysis revealed that there were dynamic structural adaptations during digestion: while non-digested myoglobin exhibited octahedral coordination, gastric conditions caused distorted 5-coordinate geometry, with complete reversion to octahedral coordination after the intestinal stage. These reversible changes suggest a protective mechanism that preserves iron absorption while allowing the necessary structural flexibility during the gastrointestinal digestive process.
This is the first time that the behavior of heme iron has been characterized at a molecular level during complete *in vitro* digestion, providing detailed insights into its structural transformations. This study demonstrates the indispensable utility of XAS in nutritional iron research and contributes to the multiscale understanding of nutrient behavior in food systems

Keywords:
XAS, iron, digestion, speciation

Acknowledgements:
This work was funded by the European Union's research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101207610, and the Villum Fonden (37759) through the Villum investigator award. We acknowledge the MAX IV Laboratory for beamtime on the BLADER beamline under proposal 20250054. Research conducted at MAX IV, a Swedish national user facility, is supported by Vetenskapsrådet (Swedish Research Council, VR) under contract 2018-07152, Vinnova (Swedish Governmental Agency for Innovation Systems) under contract 2018-04969 and Formas under contract 2019-02496.

Towards the development of food delivery systems by making use of microgel stabilized emulsions

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Microgels are intriguing colloidal entities that exhibit properties of both particles and hydrocolloids. In recent years, there has been a growing interest in exploring the potential of microgels to serve as emulsifiers. Furthermore, microgel stabilized emulsions could have great potential as protective systems for valuable nutrients in the dispersed phase of the emulsions and at the same time due to their environment responsiveness to serve as delivery systems for the same compounds. This study focuses on the development of alginate-chitosan microgel stabilized emulsions as food delivery systems. Microgels were formed via shear rupture of macrogels (top to bottom approach), a method which is easy to apply for the food industry. Different chitosan/alginate ratios and different levels of pH were examined. For the emulsions medium fatty acid chain triacylglycerol oils were used as the dispersed phase and vitamin D was added as the bioactive nutrient. The interfacial properties of the systems (determined via dynamic interfacial tension measurements and transient relaxation measurements) were compared with their structural properties determined via confocal laser microscopy (CLSM), and time-domain nuclear magnetic resonance (TD-NMR) as well as with the emulsion stability during storage. The performance of the delivery systems under different pH corresponding to typical food pH and typical pH in the gastrointestinal tract is examined. The potential to use these systems as future delivery systems for targeted nutrition is discussed.

Keywords:
microgels, emulsions, delivery systems

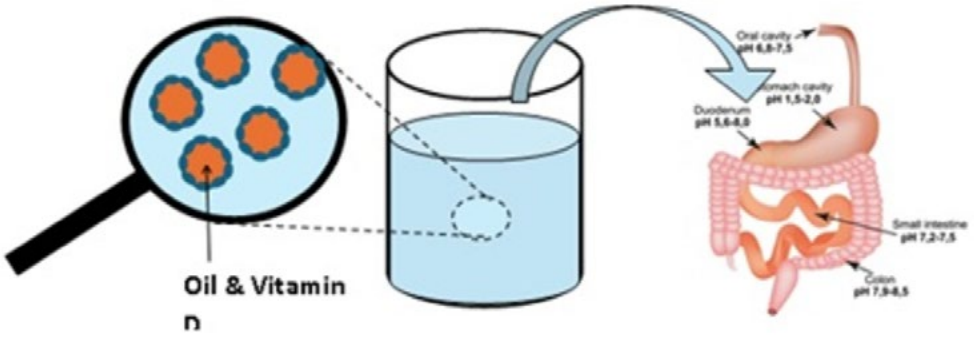

Figure 1. Scheme of the structure and application of the microgel stabilized emulsions.

Fingerprinting Protein Adsorption Classes to Identify 'Ideal' Plant Protein-Based Emulsifiers

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Surfactants derived from petrochemicals are well classified and specifically designed for colloidal stabilization applications in industrial, food and bio colloids. However, due to their origins, these surfactants are not sustainable and can cause bio-toxicity. Therefore, proteins, especially derived from plants, can be considered as green surfactant to replace synthetic surfactants in food and soft matter formulations. However, proteins are poorly classified rendering their application for surfactant applications more arbitrary experimentation than targeted design. To address this gap, we present a systematic data driven approach that integrates data science with colloidal physics using Self-Consistent Field Theory (SCFT) modelling. This approach predicts adsorbed shapes of proteins from their primary amino acid sequences. We applied this approach for the first time to a large database of plant-derived proteins, simulating their adsorption and identifying emergent adsorbed shape (e.g.: loop-like, train-like) at interfaces. These adsorbed shapes were used to functionally cluster proteins using unsupervised machine learning (ML)-based clustering. By comparing the proteins in these clusters with surface-active agent, we uncover sequence features that influence adsorption properties. We benchmarked our functional clustering with state-of-the-art Protein Language Models (ProteinLM) such as ESM-2 and ProtBERT, to further understand the important sequence features that play a role in adsorption and adsorbed shape. For instance, our results show that the number of hydrophobic amino acids of a protein only weakly correlates ($R^2 = 0.3$) with its propensity to adsorb, challenging state-of-the-art in protein surfactant science. Finally, we validated experimentally the results using a combination of interfacial tension, Laser diffraction and confocal laser scanning microscopy in few plant proteins (identified from the clusters) in their disorder architecture showing emulsion formation and emulsion stability of those disordered plant proteins resembling those of dairy proteins. Overall, this study demonstrates the practical relevance of this new data science-driven approach, paving the way for rational protein design.

Keywords:
Plant Proteins, Machine Learning, Emulsions, Colloids, Surface Science

Acknowledgements:
Acknowledgement: Simha Sridharan acknowledges the funding from UKRI Guarantee fund for Marie Curie Postdoctoral Fellowship (EP/Z000785/1)

Predicting random jamming-induced repulsive gelation in sodium caseinate-stabilized polydisperse nanoemulsions by combining the entropic, electrostatic, interfacial and steric interactions

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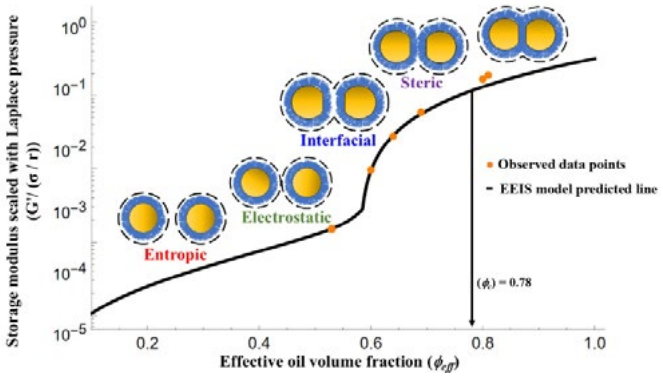
Repulsive emulsions exhibit a progressive transition from viscous liquid to viscoelastic gel states as the oil volume fraction (ϕ) increases [1]. These transitions arise from inter-droplet interactions involving entropic, electrostatic, interfacial, and steric forces as the droplets come close to each other with a progressive increase in ϕ . In ionic small molecule emulsifier-stabilized monodisperse emulsions, the balance among these contributions can be determined using the Entropic–Electrostatic–Interfacial (EEI) model developed by Kim et al. [2]. The EEI model predicts the critical volume fraction (ϕ_c) for maximal random jamming (ϕ_{MRJ}), where the repulsive oil droplets are close-packed, leading to a sudden change in their rheology and the formation of an elastic gel. In this study, the EEI model was extended to include steric repulsion, resulting in the Entropic–Electrostatic–Interfacial–Steric (EEIS) framework. To validate the model, sodium caseinate-stabilized nanoemulsions ($d_{3,2} \approx 271$ nm, relative polydispersity 0.61) were prepared using high-pressure homogenization and size-fractionated through three-step ultracentrifugation to obtain pseudo-monodisperse emulsions with a range of droplet sizes and polydispersity. Results showed that elasticity increased with increasing ϕ due to droplet crowding, leading to ϕ_{MRJ} [3]. Moreover, smaller droplets exhibited higher elasticity, shifting the ϕ_{MRJ} to a higher value, attributed to the increase in effective oil volume fraction (ϕ_{eff}) resulting from the greater interfacial shell layer thickness from the combined effects of the steric barrier and its surrounding electrostatic charge cloud [4]. The EEIS model predicted the transition of normalized elasticity (G′ scaled with Laplace pressure) as a function of ϕ (Figure 1). The Figure shows that, at low ϕ (<0.5), the system was dominated by entropic forces arising from thermal motion and excluded volume effects. With increasing crowding ($\phi \approx 0.55–0.6$), the electrostatic contribution sharply increased, followed by interfacial interactions ($\phi \approx 0.6–0.78$), marking the transition from a liquid-like to a glassy state. Beyond the critical jamming point ($\phi_c \approx 0.78$), steric interactions emerged as the dominant repulsive force due to overlap of adsorbed steric layers, leading to a steep rise in G'_p and the formation of an elastic gel. The results of the model will be used to understand the jamming transition of polydisperse emulsions and establish a relationship between ϕ_c and polydispersity. These findings will enhance understanding of the role of droplet size distribution in the formation and tailoring of protein-stabilized emulsion gels, providing new insights for food structuring and soft matter design.



Storage modulus scaled with Laplace pressure (G′/(σ/r)) as a function of effective oil volume fraction (ϕeff), showing the transition of entropic-electrostatic-interfacial-steric regime, with predicted critical jamming point (ϕc ≈ 0.78).

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Predicting in vitro digestion of gelatin gels from videos using machine and representation learning

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In vitro digestion models enable the study of gastrointestinal processes, e.g., the digestion of proteins. While models like the INFOGEST protocol standardize *in vitro* digestion conditions [1], methods for determining digested products vary, and correlations between *in vitro* and *in vivo* digestion are discussed [2]. This study explores gelatin-based hydrogels crosslinked with transglutaminase (TGase) as model substrates to investigate protein digestion using real-time video collection and machine learning (ML), a tool already employed in gastrointestinal diagnostics [3].

Gelatin is widely used in food and pharmaceutical applications for its gel-forming ability and biocompatibility [4]. Here, gelatin gels were immersed in simulated gastric media with varying pH, ionic strength, and pepsin concentration [1]. Swelling behavior and degree of hydrolysis (DH) were monitored over time, while video sequences were acquired through a camera probe and processed using ML models. A representation learning-based approach, combining a convolutional neural network (CNN) with a multi-layer perceptron (MLP), was compared to a conventional feature extraction method using hue-saturation-value (HSV) features with an MLP. Results showed that the CNN-based models outperformed the HSV-based approach in identifying digestion conditions and estimating DH, likely due to the superior spatial feature representation achieved through learned representations rather than manually defined features. Pepsin concentration and pH of the media were reliably classified, demonstrating the model's sensitivity to subtle visual changes even with limited data. TGase-crosslinked gelatin gels exhibited varying swelling and digestion rates, influenced by pH and ionic strength.

These findings highlight the potential of ML-driven video analysis for decoding digestion dynamics in real-time and exemplify the combination of deep learning methods and advanced *in vitro* models for food and nutrition research.

Keywords:
Gelatin, protein, pepsin, computer vision, image similarity analysis, deep learning, video change detection

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Which molecular parameters predict foaming properties – A soft matter approach

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Predictive tools are needed to provide rapid, accurate values for techno-functional behavior of ingredients. Especially, as new alternative protein sources and varieties are constantly being explored and produced. Experimental assessment of each ingredient is time consuming and resource intensive. However, developing reliable predictive models, using e.g. neural networks or other machine learning models, requires good quality data. But at this point, it is unknown which molecular data from protein ingredients is needed to build accurate models. In this work, we used a soft matter approach to identify molecular parameters that best predict foaming performance of soy proteins, obtained via lab- and industrial-scale extraction. The analysis showed that solubility and surface tension are general predictors of foamability because high solubility leads to faster diffusion of particles to the interface, significantly lowering the surface tension. However, for foam stability, solubility is a general predictor, while in laboratory-extracted proteins, enthalpy, particle size, the 11S/7S ratio, and surface charge also play critical roles. Hence, the predictive power of molecular properties strongly depends on processing history, making generalization across lab-extracted and commercial proteins challenging. These findings provide deeper insights into the molecular parameters that determine the foaming properties of lab-extracted and commercial proteins. The determined key parameters provide a predictive framework for the foaming behavior of soy proteins and offer a foundation for modeling protein functionality in general.

Keywords:
Key words: soy proteins, functionality prediction, molecular predictors, foams

FLASH COMMUNICATION

From olive waste to bioactive colloids: valorization of maslinic acid through solid lipid nanoparticles

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The olive oil industry generates vast quantities of by-products that represent an untapped reservoir of high-value compounds. Maslinic acid (MA), a pentacyclic triterpene abundant in these residues, possesses significant antioxidant, anti-inflammatory, and antitumoral properties. However, the successful translation of its bioactive profile into practical applications is hindered by its low aqueous solubility (3.6 μg/L) and consequent poor bioavailability. To overcome these physicochemical limitations and revalorize this agro-industrial waste, this work aimed to engineer MA-based Solid Lipid Nanoparticles (MA-SLNs) as a sustainable and highly stable nanoplatform designed for the future delivery of hydrophobic drugs for cancer treatment. We synthesized MA-SLNs via a solvent-displacement method, and physicochemical properties, including the organic-to-aqueous phase ratio and surfactant concentration, were optimized to yield highly monodisperse nanoparticles of approximately 130 nm with a strong negative surface charge (-35 mV). To prove the capacity of this system as a versatile co-delivery platform, curcumin was encapsulated as a model highly hydrophobic molecule, demonstrating enhanced encapsulation efficiency, structural integrity, and sustained retention over time. Furthermore, the biological performance of the engineered nanocarriers was evaluated in tumoral cell lines to validate their capability to internalize and act as future vehicles for complex therapies. Confocal laser scanning microscopy revealed rapid and efficient cellular internalization of the MA-SLNs in these *in vitro* models, successfully overcoming the biological transport barriers associated with the free compound. Additionally, *in vivo* biodistribution studies in murine models demonstrated a highly favorable physiological profile. The nanocarriers maintained their physical stability in systemic circulation and showed safe accumulation patterns in highly irrigated organs, with no signs of acute toxicity or macroscopic tissue alterations. These comprehensive results highlight the potential of this nanotechnological approach to transform olive oil milling waste into advanced, bioavailable colloidal systems for pharmacological applications.

Acknowledgements:
The authors thank MCIN / AEI / 10.13039 / 501100011033/ FEDER for funding PID2022-140151OB-C21 and PID2022-140151OB-C22 projects.

Thermodynamic Incompatibility and Phase Inversion in Emulsions Stabilized by Uncracked Vegetal Byproducts

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Optimizing the valorization of byproducts from the agri-food industry is highly relevant given the large quantities of valuable matter that is still currently lost, and developing sustainable pathways to recover and upcycle this biomass is therefore imperative. In this context, research is made in the use of byproducts minimally processed for the stabilization of clean-label dispersed systems. These ingredients, that show complex compositions, offer a promising route toward circular and resource-efficient formulations. [1][2]
The present study focuses on mixes of micronized pistachio shell (PS) and rice bran wax (RBW) powders to stabilize emulsions. Both O/W and W/O emulsions could be stabilized with these byproducts, depending on their mass fractions. Furthermore, bi-continuous systems were also obtained with close proportions of oil-water and PS-RBW. These results were directly related to the chemical composition of the 2 byproducts. PS contains a high fraction of structural polysaccharides (around 80%, with 10-20% of cellulose and 30-40% of hemicellulose) and approximately 5% of proteins. A recent study demonstrated the foaming and emulsifying properties of the PS powder [3]. By contrast, RBW contains significantly lower protein and fibrous contents (approximately 2% and 40% respectively), and studies showed that this ingredient is composed predominantly of long-chain fatty-acid crystals, conferring increased hydrophobicity and a strong affinity for the oil phase [4].
A phase diagram was constructed to delineate domains corresponding to O/W, W/O and bi-continuous systems. Stability was assessed across the formulation space, and stable systems were characterized by confocal microscopy. Formulations enriched in oil and RBW preferentially produced W/O emulsions, with aqueous droplets of several tens of micrometres. Conversely, more aqueous formulations fortified with pistachio-shell powder (PS) yielded O/W emulsions containing much smaller oil droplets (typically a few micrometres). Considering the bi-continuous system that was also obtained, various stabilization mechanisms can take place: in some regions (e.g. bi-continuous) a hybrid mechanism takes place, whereas in more extreme formulations one ingredient predominates. In particular, interfacial protein adsorption appears to drive O/W formation, while abundant insoluble particles and RBW favour Pickering-type stabilization of W/O systems by functionalizing the oil phase.
These results contribute to the knowledge in formulation of dispersed systems using upcycled materials with complex compositions and offer promising prospects for minimizing processing while maximizing material valorization in dispersed system stabilization such as food and cosmetic products.

Keywords:
Clean-label Emulsions, Phase Inversion, Bi-continuous System, Vegetal Byproducts, Upcycling

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Rescaling of flow curves for food emulsions

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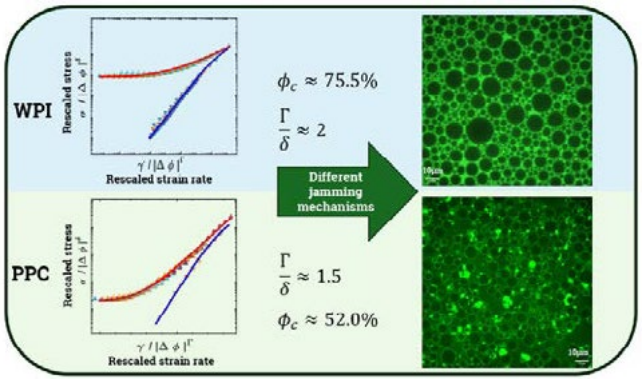
There is growing interest in replacing dairy proteins with plant-based counterparts in food emulsions. This substitution is likely to alter how droplets interact, because plant-based emulsions contain a substantially higher insoluble protein fraction. Plant proteins can therefore act as Pickering particles, which significantly alter interfacial properties. In this study, we mechanically characterize emulsions stabilized by dairy or plant proteins by measuring their steady-state flow curves near the jamming point. For both protein types, flow curves can be rescaled onto master curves above and below jamming. However, we find two important differences. First, plant proteins dramatically reduce the jamming volume fraction compared to its value for soluble dairy proteins. And second, the scaling exponents required to collapse the data differ significantly. Using microscopy and an effective packing fraction in Pickering emulsions, we relate these differences to the interfacial microstructure of the emulsions. These findings provide new insights into how insoluble plant protein fractions alter emulsion behavior, which is essential for the rational design of plant-based food formulations with desired flow properties.

Keywords:
Emulsion, Rheology, Pea protein, Whey protein, Rescaling



From left to right: Rescaled stress - Rescaled strain curves for whey protein isolate (WPI) and pea protein concentrate (PPC), their corresponding critical packing fractions and rescaling coefficient ratio and the resulting difference in emulsion microstructure.

In situ gas foaming of plant-based dispersions into porous food structures

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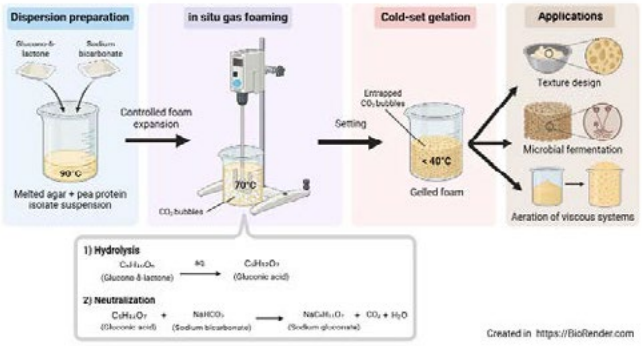
Porous food materials are central to texture perception, mass transfer, and cell growth in both food and bioprocessing applications. Conventional foaming methods, which rely on mechanical aeration and interfacial stabilization, are highly effective for low-viscosity and surface-active systems but fail when applied to highly viscous or poorly surface-active dispersions. This limitation constrains the design of dense, plant-based matrices into functional porous structures. Here, we propose in situ gas foaming as a novel approach to aerate viscous food dispersions through controlled gas generation within the material itself. Although in situ gas foaming is well established for structuring polymer melts into microcellular materials, its potential as a colloidal templating mechanism for foaming viscous food dispersions remains largely unexplored.
Gas generation was induced in situ via a food-grade acid-base reaction between glucono-ð-lactone and sodium bicarbonate, producing CO_2 within melted agar-pea protein isolate dispersions. This process enabled foaming across a broad viscosity range and showed a trade-off between foam expansion and structural stability. Low-viscosity dispersions showed the highest initial expansion but also the greatest collapse during gelation, whereas highly viscous systems formed denser yet more stable foams. The highest post-gelation expansion occurred at intermediate viscosity, indicating an optimal balance between bubble growth and viscous resistance.
In this work, we demonstrate the potential of in situ gas foaming as a colloidal structuring approach for generating porous structures in viscous food dispersions. This opens new opportunities for designing functional materials in food and bioprocessing applications.

Keywords:
Foaming, in situ gas foaming, plant protein dispersions, rheology, foaming properties, porous materials



Schematic representation of in situ gas foaming as a colloidal structuring approach for viscous food dispersions. Gas is generated in situ through a food-grade acid-base reaction between glucono-ð-lactone and sodium bicarbonate, producing CO_2 within melted agar-pea protein dispersions. Upon cooling,

Oleosomes (natural lipid droplets) as building blocks for structured emulsion gels

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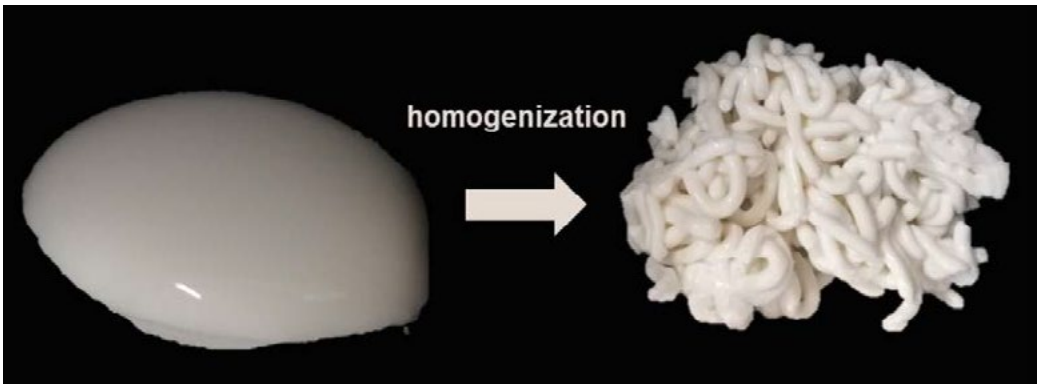
Structured emulsion gels are semi-solid systems in which liquid oil is entrapped within a three-dimensional network formed by structuring agents [1]. These systems have attracted significant interest in food, pharmaceutical, and cosmetic applications as healthier alternatives to solid fats. In this context, oleosomes, natural lipid droplets derived from plant seeds, are promising candidates for emulsion gel formation due to their semi-solid nature and interfacial stability provided by their phospholipid-protein membranes [2]. At high ζ-potential values, oleosomes act as repulsive emulsions, where electrostatic interactions among densely packed droplets can induce gelation. Here, building on this repulsive behavior, we aimed to create a structured material by downsizing the oleosomes using a high-pressure homogenizer (20,000 psi, six cycles). Rheological (SAOS, LAOS) characterization revealed that reducing droplet size ($D_{[4,3]}$ from 3.92±0.02 to 0.80±0.04 μm) markedly increased the elastic modulus (from 120 to 5600 Pa) and the intensity of G'' overshoots due to structural relaxation, suggesting the formation of a repulsively jammed state upon high-pressure homogenization. Although the ζ-potential remained unchanged (46.92±0.54 and 43.57±0.87 mV), the enhanced elasticity indicates denser packing due to the increase in effective volume fraction of the oil droplets [3]. Thus, these findings highlight that oleosomes can be engineered as a self-structured material to develop natural structured emulsion gels that mimic the textural and functional properties of solid fats.



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Acknowledgements:

This work was supported by Botaneco Inc.

Spray-chilled oleogel particles enabling hierarchical oleogel-in-oleogel structures

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The food industry relies heavily on saturated fats because they solidify at room temperature and form crystalline structures, which serve as delivery and protective mechanisms while providing unique sensory properties. However, excessive intake of these fats can lead to obesity and increase the risk of cardiovascular disease, metabolic syndrome, and type 2 diabetes. Replacing saturated fats with oils rich in polyunsaturated fatty acids offers a promising strategy to improve health outcomes and potentially reduce healthcare costs. Structured lipid systems, such as oleogels, which immobilize liquid oils within three-dimensional networks, have garnered interest due to their versatility and potential to mimic the textural and functional properties of conventional solid fats while delivering essential fatty acids. Despite their advantages, achieving simultaneous control of structure, oxidative stability, and digestibility remains a major challenge, and their high caloric content limits unrestricted consumption.
Building upon our first-generation ethylcellulose-based oleogel-in-oleogel (OG/OG) system [1], which leverages the kinetic confinement properties of the ethylcellulose network to slow lipid digestion, this study introduces a second-generation OG/OG architecture using a mixture of β-sitosterol and γ-oryzanol (BSGO), gelators with recognized health benefits and a lower crystallization temperature, facilitating its handling. The BSGO combination forms tubular crystalline networks that entangle into fibre-like structures, contributing to controlled digestibility and potential cholesterol-lowering effects. A spray chilling approach enables the formation of coated, micron-scale BSGO oleogel particles, which act as internal fillers within an outer oleogel matrix, creating a hierarchical OG/OG structure. The spray-chilled BSGO particles offer a smaller, more uniform architecture compared to the larger first-generation ethylcellulose beads obtained by prilling, a technology that inherently limits particle size reduction. This smaller and more uniform structure facilitates incorporation into the outer oleogel. The resulting composite OG/OG system displays uniform morphology, structural integrity, controllable digestibility and compatibility with various continuous oleogel matrices, demonstrating potential for incorporation into more complex food products [2]. This work advances the design of hierarchical oleogel architectures by integrating spray-chilled particle formation, particle coating, kinetic confinement, and lipid physical state control, providing a versatile strategy for engineering next-generation functional oleogels with tailored digestibility and improved applicability.

Keywords:
oleogel, oleogel-in-oleogel, spray chilling, fat replacement, lipids

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Acknowledgements:
The authors acknowledge the University of Helsinki (decision letter number HY/217/05.01.07/2020), and the Finnish Cultural Foundation for their funding.

Detailed characterization and gelation mechanism of mung bean albumin and globulin fractions

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Plant protein isolates are increasingly used in food formulations, particularly to produce plant-based yogurts [1]. However, their gelling properties remain difficult to control and standardize. Therefore, a comprehensive understanding of the gelling behavior of plant proteins is essential, particularly that of globulins and albumins, which are the two major protein fractions in most plant sources, including pulses [2].
This research investigates proteins from mung beans, an emerging and promising protein source that remains under-researched compared to other common pulses [3], yet is gaining increasing attention for its remarkable gelling properties [4]. The study first involved the production of mung bean albumin and globulin fractions, followed by characterization and analysis of their gelling properties.
Mung bean protein isolates were obtained by alkaline solubilization of mung bean flour at pH 9 for 2 h, followed by centrifugation and ultrafiltration-diafiltration (UF-DF) of the supernatant using a 30-kDa molecular weight cut-off membrane. Purified albumin and globulin fractions were obtained by isoelectric precipitation at pH 4.5 followed by centrifugation. The globulin was recovered from the pellet, while albumin from the supernatant was further purified by UF-DF. The globulin and albumin fractions contained 88.44% and 80.72% protein, respectively, as determined by the Dumas combustion method. Both fractions were further analyzed for their proximate composition and physicochemical properties, including solubility (pH 2-8), particle size, thermal behavior and secondary structure. Gelling properties were then investigated, starting with least gelation concentration, followed by water-holding capacity, rheological behavior, microscopic structure, and analysis of molecular interactions within the gel networks.
Notable differences were observed between the two fractions. Albumin fraction displayed a constant solubility (~60%) at all pH values, while globulin fraction followed a U-shaped curve with a minimum at pH 4.0 (26.10%) and a maximum at pH 8 (91.44%). The relatively low solubility of albumins was attributed to protein aggregation during purification. Additionally, albumins were characterized by smaller soluble particle size and a secondary structure enriched in α-helices. These features are consistent with its lower minimum gelation concentration (4%) compared to the globulin fraction (8%). However, the water retention capacity of albumin gels (80.3%) was lower than that of globulin gels (96.2%) at 8% proteins, suggesting a less firm network for the albumin fraction. Rheological and microscopic analyses confirmed these results, showing a higher final elastic modulus (G') for globulin gels (8908 Pa versus 1081 Pa for albumin gels) and a tighter gel structure. In contrast, the albumin fraction formed a loose and porous network with coarse particulate features, attributed to the aggregated conformation of albumins. Globulin gels were also characterized by increased protein incorporation and more extensive intermolecular bonding, primarily formed through hydrophobic interactions. In contrast, albumin gels were formed mainly through electrostatic interactions. Based on these findings, a gelling mechanism was proposed for each fraction, providing valuable insight into the distinct roles of albumins and globulins in the gelation of mung bean protein isolates.

Keywords:
Mung bean, proteins, albumin, globulin, surface properties, gelling properties, microstructure, protein interactions

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Understanding the development of food-grade antibacterial packaging film

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Electrospun films for food packaging remain underexplored yet are considered promising for active delivery and barrier control. This study aims to build zein-based electrospun films with stable fiber morphology and to prepare them for future antioxidant and antibacterial use in food applications. Zein and hydroxypropyl cellulose (HPC) are used as materials for the formation of films that are easy to handle. Meanwhile, phenolic actives such as quercetin (Que) are added to provide films with antioxidant and antibacterial properties.

85% v/v ethanol was used to dissolve total solids, which were composed of a mixture of zein and HPC at mass ratios of 9:1, 8:2, 7:3, and 6:4. Que was added at different concentrations to control the morphology of electrospun fibres and also add antioxidant and antibacterial potential.

The SEM results showed statistical differences across different mass ratios. At a zein:HPC ratio of 9:1, many large beads were observed, and frequent bead collapse was observed. At 6:4, numerous smaller beads were observed along the fiber length. In contrast, ratios of 8:2 and 7:3 were associated with fewer visible defects and more continuous networks. Upon Que addition, existing beads were eliminated at lower concentrations, and the fibres became smoother and more uniform. Moreover, it was also found that as the quercetin concentration increased from 0.5% to 1.5% w/v, the fibers tended to aggregate and form ribbon-like fibers, and beads appeared again and became more frequent. Ribbon or flattened fibers appear when the jet does not dry fast enough relative to stretching. Additionally, the porous structure of electrospun fibers allowed Que to be released in a sustained manner, enabling long-lasting antioxidant and antibacterial effects.

By coupling morphology control with controlled release, a route is created to active films that can protect food quality, limit oxidation and microbial growth, and extend shelf life. The approach is compatible with clean label formulations and low temperature processing, which facilitates translation to scalable packaging formats.

Keywords:
Electrospinning; Electrospun film; Antioxidant; Release control; Antibacterial

Improvement of functional properties of hemp proteins by chemical and enzymatic modifications

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Rapid population growth will increase demand for protein-rich foods. Plant proteins offer a cost-effective, nutritious alternative with lower saturated fat content that meets daily nutritional needs while supporting modern dietary trends that emphasise health, wellness and sustainable food choices [1,2]. Hemp (Cannabis sativa L.) oilseed is gaining attention as a multipurpose crop with low environmental impact that contains low levels of Δ9-tetrahydrocannabinol (THC, <0.1–1%). This is because, unlike most oilseeds, hemp oilseeds are low in anti-nutritional compounds and the protein extracted from the oilseed cake after oil extraction, has a rich nutritional protein profile comparable to egg white and soybean [3].
The potential use of protein in food applications depends largely on its functional properties. The structure of a protein is crucial in determining its functionality as it is influenced by hydrophobic, non-covalent and electrostatic interactions. Physical, chemical, and biological techniques can be used to modify protein structure [4].
This study investigated the impact of chemical lyophilization (acylation using fatty acid chloride) and enzymatic cross-linking (using microbial transglutaminase) on the functional properties of hemp protein. Dynamic light scattering (DLS) and zeta potential analysis revealed different responses to various modification methods in terms of changes in particle size and surface charge. The water- and oil-holding capacity, foaming ability, emulsion activity, and stability were all higher for the chemically or enzymatically modified proteins than for the unmodified proteins. This demonstrates the improved functionality and enhanced applicability of these proteins.

Keywords:
Plant Proteins, Protein Modification, Functional Properties

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Agro-industrial avocado residues as functional additives for cellulose-based food packaging

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The development of food packaging materials based on renewable polymers is a major challenge within the transition towards a circular bioeconomy. In this sense, cellulose-based films are promising biodegradable alternatives. However, their high-water sensitivity limits their performance under humid conditions.
In this work, lipid-rich extracts obtained from agro-industrial avocado residues were investigated as functional additives to tailor the properties of glycerol-plasticized cellulose-based bioplastics. First, the lipid fraction was extracted using chloroform, and the process was optimized through experimental design, establishing 55 °C and 50 min as optimal conditions. Then, those extracts were incorporated into cellulose-glycerol formulations at different concentrations (0-20 wt.-%), and the resulting films were characterized in terms of optical, morphological, mechanical, hydrodynamic, and antioxidant properties. Transparency values slightly decreased with increasing avocado extract content but well above the threshold of transparent materials while SEM revealed a good dispersion of the extracts into the cellulose matrix. Mechanical testing revealed no significant changes in the main tensile parameters. In contrast, hydrodynamic properties were markedly improved. Water uptake values at 100% relative humidity were reduced by approximately 20% and a significant reduction in water vapor transmission rate was observed. Moreover, the films exhibited antioxidant capacity, with radical scavenging activity values of around 20% after 96 h. Finally, overall migration using Tenax® as a dry food simulant was tested to confirm the compliance with current regulatory limits. In view of these results, plasticized cellulose-glycerol bioplastics with avocado extracts can be proposed as functional, high barrier food packaging materials.

Keywords:
Cellulose; Avocado residues; Bioplastics; Active food packaging; Circular bioeconomy.

Acknowledgements:
This work has been partially supported by the Spanish "Ministerio de Ciencia, Innovación y Universidades" project RYC2023–042483-I/ MICIU/AEI/10.13039/501100011033 (cofinanced by the ESF+) and by the Spanish Research Council (CSIC) project 20254AT003.

Extraction and processing shape the structural and emulsifying properties of pea proteins

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The use of pea proteins in food systems is gaining attention due to their nutritional value and environmental benefits. Yet, the effects of extraction and processing conditions on protein structure and how these influence o/w emulsion stability are not yet well understood. This study investigated the impact of different extraction methods and processing steps (thermal treatment, drying techniques) on the structural and functional properties of pea proteins. A commercial pea protein isolate was used as a reference.

Extraction conditions were found to affect pea protein (micro)structure and emulsifying performance. Salt extraction and alkaline extraction at pH 7.5 yielded pea proteins with similar structural characteristics, whereas alkaline extraction at pH 11 resulted in greater denaturation and aggregation of the proteins. Despite this, pea proteins extracted at pH 11 formed emulsions with the smallest droplet sizes. The salt-extracted protein presented the best creaming stability. Drying methods had only a minor effect on pea protein structure. In contrast, thermal treatment had a more substantial impact, resulting in increased aggregation and emulsions with larger droplets and lower stability, independent of the extraction conditions.

These results demonstrate that processing-induced structural changes have a significant impact on pea protein functionality, particularly in o/w emulsions. Understanding the relationships between processing, structure, and function is crucial for developing high-performance plant-based food ingredients such as emulsifying agents.

Keywords:
emulsion stability, pea protein, plant-based ingredients, processing

In operando-SAXS analysis of multiscale structural changes in food dispersions during in vitro digestion processes

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The multiscale structures in food play a critical role in determining the physicochemical properties such as stability, texture before oral processing, and digestibility and absorption during gastrointestinal bioprocessing. Therefore, a series of methods has been widely developed to analyze the structure of foods at various scales, ranging from the molecular level to the macroscale. Among these techniques, small- and wide-angle X-ray scattering (SAXS and WAXS) have been gaining increasing attention because of their potential to characterize the internal structures of materials non-destructively and at the nanoscale. Moreover, the techniques provide nanometer-resolution images in their native state, without the need for freezing the sample.

The structural hierarchy of foods and beverages is partially or mostly broken down and simultaneously reorganized during digestion processes in the human gastrointestinal tract. To achieve efficient and controlled delivery and absorption of major and minor nutrients, including bioactive compounds, it is essential to understand the multiscale structural changes that occur during digestion processes. Several studies have previously reported analyses of in vitro simulated gastric processes using SAXS to understand structural changes in lipid-based systems. Here, we report the development of an INFOGEST simulated digestion model integration into the SAXS system. The new INFOGEST-SAXS tool enables the study of nanostructure-digestion correlations *in operando* and for a broad range of food materials, including proteins, lipids, and fibres. Our new *in vitro* digestion-SAXS tool deepens the understanding of multi-structural changes throughout the gastrointestinal tract.

In this contribution, we will focus on structural changes during the digestion of a) model plant protein in solution, b) plant protein microgel dispersion, and c) plant-based milks (e.g., soymilk). The samples will undergo bioprocessing in a temperature-controlled digestion chamber, where they are step-wise mixed with gastric and intestinal juices, including amylases, proteinases, and lipases, according to the well-established INFOGEST protocol. An aliquot of the digesta in the chamber is constantly circulated through a pump system composed of a pipe and a flow-through glass capillary, where the digesta is exposed to X-ray. The time-dependent structural changes in the average scattering patterns obtained within a fixed irradiation time will be understood in comparison with conventional methods for digestion analysis.

Keywords:
Small-angle X-ray scattering (SAXS); in vitro digestion; multi-scale structure

Bridging Lubrication and Sensory Perception in Plant-based Beverages

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Plant proteins are increasingly used in foods and plant-based beverages. However, these products often exhibit undesirable sensory characteristics, such as dryness, astringency, and bitterness, which limit their acceptance. It is well recognised that texture attributes such as smoothness, creaminess and fattiness are not solely determined by rheological properties, but are also strongly influenced by lubrication behaviour. Despite the growing interest in this area, there is still limited understanding of the contribution of individual ingredients and the combined effects of multiple components on lubrication properties of complex foods, as well as how specific lubrication profiles relate to sensory perception. Therefore, this study investigated the lubrication behaviour of model plant protein-based beverages containing protein aggregates, oil droplets and polysaccharides, aiming to clarify the mentioned issues. The effects of oil droplet concentration, aggregate size and polysaccharide type were examined. Increasing oil content effectively reduced friction, and a synergistic lubrication effect was observed when large protein aggregates were mixed with oil droplets. However, this effect disappeared after the reduction of the aggregate size by homogenisation. In contrast, adding polysaccharides at equal viscosity did not significantly change friction, indicating that the observed synergy was not viscosity driven but related to the specific contribution of protein aggregates. Sensory evaluation revealed that smaller aggregates led to a reduction in grittiness, higher oil content enhanced creaminess, and polysaccharides mainly increased perceived thickness and creaminess. A correlation analysis showed that viscosity was associated with thickness, creaminess and dryness, while friction in the mixed regime (10 mm/s) correlated with perceived creaminess. Overall, this study elucidates how various components within multi-component food systems influence sensory perception and how tribological behaviour is linked to sensory quality in plant protein-based beverages.

Keywords:
Lubrication; Plant protein aggregates; Oil droplet; Polysaccharide type; Sensory properties

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Arabinoxylan-protein complexes as new structuring ingredients for meat replacers: effect of enzymatic treatments on gel structure

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Many plant-based foods consist of mixed biopolymer networks, where controlled interactions between components allow the design of specific mechanical and structural properties. In this study, we analyse the enzymatic crosslinking between wheat bran arabinoxylans (WBAX) and plant proteins, as a model for double network hydrogel formation. Ferulic acid residues in WBAX and amino acids such as tyrosine, cysteine, and tryptophan provide reactive sites for oxidative enzymes. We study how protein type, functional group availability, and enzymatic specificity influence the formation, structure, and viscoelastic behavior of arabinoxylan–protein networks, and evaluate the potential of WBAX–protein complexes as space-spanning networks, as well as suspended structures in model plant-based systems.
Plant proteins from pea, potato, faba, soy, and oat were crosslinked with laccase, peroxidase, or glucose oxidase in the presence of WBAX. Following incubation and heat treatment, the resulting gels were analyzed for rheological (time sweeps, temperature-dependency, and LAOS) and microstructural properties. Enzymatically treated samples showed higher viscoelastic moduli than untreated or single-component systems, indicating synergistic interactions and the formation of intermolecular WBAX–protein bonds. The effect was most pronounced in proteins with weak gelation, highlighting the potential of this approach to enhance their gelling performance. SDS-PAGE confirmed the formation of high-molecular-weight conjugates, while FTIR spectroscopy indicated strong hydrogen bonding between WBAX and all protein types. Confocal microscopy revealed interconnected network structures, which varied with ingredient ratio, WBAX ferulic acid content, and reaction conditions, reflecting the degree of crosslinking achieved.
In conclusion, the enzymatic crosslinking of plant proteins with WBAX caused a general increase in gel strength in all tested protein types. The extent of crosslinking was highly dependent on the ferulic acid content of WBAX and on the reaction conditions, while the gel structure was also affected by the ratio of the ingredients. Overall, we provide the foundation for the development of a new type of structuring systems for plant-based meat analogues.

Keywords:
Arabinoxylans, plant proteins, enzymatic texturization

Electrospinning of hybrid lipid-polymer fibres for cultured meat applications

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Electrospinning is a versatile technique to produce scaffolds mimicking the extracellular matrix of native tissue and has received considerable attention recently in cellular agriculture and alternative meat manufacturing. Among the different materials employed, charged proteins and polymers are the most highly relevant to food applications. However, their electrospinning remains a significant challenge due to their intrinsic properties such as high viscosity, surface tension, and strong hydrogen bonding capacity. These characteristics hinder effective chain entanglement, fibre formation, and cross-linking, limiting the development of stable fibrous structures. Nevertheless, given their role in supporting tissue integrity and influencing cellular behaviour, the incorporation of biomimetic polymers into cultured meat systems offers a promising approach to enhancing tissue functionality and improving overall product quality.

In this study, we present how hybrid electrospinning of lipid nanoparticles with biomimicking polymers facilitates the production of hierarchical scaffolds with tuneable functional and mechanical properties. Positively charged lipid nanoparticles, exhibiting distinct internal structures, were combined with a negatively charged biopolymer. This design aimed to promote electrostatic interactions between the nanoparticles and the biopolymer fibres and so enhance fibre formation and stability.

We have applied a thorough rheological and particle size analysis to find the optimum conditions where electrospinning can produce highly stable fibres with high cross-linking capacity, leading to maximum mechanical integrity. Beyond structural performance, cellular interactions — such as attachment within the fibrous matrix — will be emphasised to demonstrate the material's potential for supporting cell attachment and growth.

Our findings demonstrate that our hybrid mixture significantly enhances the electrospinnability of charged biopolymers through improved cross-linking and structural reinforcement.

Synergistic heat-induced gelation of mixtures from pulse and rapeseed protein: impact of pulse source

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Plant proteins from different origins, like pulses or oilseeds, differ in gelation behavior and the properties of the resulting gels. One possible approach to utilize these differences is to mix plant proteins from various origins. However, so far there is limited research on the gelation of such mixtures. Consequently, the aim of our study was to investigate the heat induced gelation of binary mixtures from soy + rapeseed (SPI+RPI) and pea + rapeseed (PPI+ RPI) proteins at various mixing ratios, in comparison to their individual protein counterparts and to further characterize the resulting gels.
To this purpose, denaturation behavior of rehydrated individual proteins (10 % protein (w/w)) and binary protein mixtures at three mixing ratios (2.5% / 7.5%, 5% / 5% and 7.5% / 2.5% protein (w/w)) was analyzed by µDSC to identify mixing-induced interactions between proteins from different origin. Gelation kinetics were analyzed in rheological temperature sweeps. After cooling, frequency- and amplitude-sweeps were performed to further characterize the rheological properties in terms of gel strength, network connectivity and deformation behavior. Additionally, water holding capacity and protein fraction involvement were evaluated to gain further insights on microstructural properties of individual and mixed gels.
Results showed significant synergistic effects in both mixed systems though with variation on investigated parameters. Mixed SPI+RPI gels showed synergistic gel strength, water holding capacity and improved SPI incorporation in gel network, especially when SPI dominated in the mixture. This is likely due to co-aggregation between SPI and RPI protein fractions that led to gel strengthening, balanced gelation kinetics and homogeneous gel microstructure. On the other hand, mixed PPI+RPI gels exhibited linear mixing effect on gel strength, yet with significant synergism on network connectivity and protein incorporation in gels at all mixing ratios. Different extent of synergism revealed by two mixed systems implied differently balanced attractive and repulsive interactions exerted by their variance in protein fraction compositions.
The synergistic heat-induced gel properties of mixtures from pulse and rapeseed protein offer potential for customizing textural properties in plant-based protein foods.

Keywords:
synergistic gel, mixed protein gelation, rheology, plant proteins

Acknowledgements:
This IGF Project 01IF22270N of the FEI is supported within the programme for promoting the Industrial Collective Research (IGF) of the German Ministry of Economics and Climate Action (BMWK), based on a resolution of the German Parliament.

Heat-induced co-aggregation of rapeseed cruciferin with pea legumin and soy glycinin: Understanding protein interactions for clean-label applications

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Plant protein aggregates are key structural elements of novel food gels formed via heat- or acid-induced protein gelation. However, protein gels based on pea or soy aggregates often lack sufficient gel stiffness, commonly addressed by additives [1]. Clean-label strategies therefore focus on protein combinations to achieve tailored functional properties while increasing consumer acceptance. Rapeseed proteins are a promising candidate for protein combination due to their high aggregation and gelation potential and wide availability as oilseed by-products [2]. However, their co-aggregation behaviour with pea or soy proteins is not yet fully understood. Since these proteins contain structurally distinct protein fractions, their individual roles must be examined to understand the mechanisms of co-aggregate formation. Therefore, this study aimed to elucidate the relationships between denaturation and aggregation of isolated rapeseed cruciferin in combination with pea legumin and soy glycinin during heat-induced co-aggregation.

For this purpose, native cruciferin, glycinin, and legumin fractions were isolated from low-processed protein sources. The denaturation characteristics of the individual protein fractions and their mixtures were assessed by micro-DSC measurements. Heat-induced aggregation and the molecular interactions driving aggregate formation were examined by viscometric temperature sweeps from 25 to 90 °C at pH 7. The composition of insoluble and soluble co-aggregates and the specific protein subunits involved were further analysed by SDS-PAGE.

During heat treatment, cruciferin formed predominantly insoluble aggregates, revealing a strong tendency for intermolecular bonding and self-association. When combined with legumin, aggregate solubility increased by 60% compared to cruciferin alone. SDS-PAGE analysis showed an even distribution of cruciferin subunits between soluble and insoluble aggregates, suggesting that legumin terminates cruciferin's self-association tendency and promotes the formation of soluble co-aggregates. Mixing cruciferin and glycinin resulted in the formation of cruciferin-glycinin complexes likely due to attractive electrostatic interactions. The associated conformational rearrangement lowered the denaturation temperature of the complexes from about 98 °C to 91 °C, compared to glycinin alone. This reduced thermal stability led to more extensive protein unfolding during heat treatment up to 90 °C, exposing additional interaction sites that accelerated co-aggregation, as reflected by a steeper increase in relative viscosity with increasing temperature. SDS-PAGE analysis further indicated additional electrostatic interactions between the glycinin basic subunit with cruciferin subunits. Consequently, a complex co-aggregation mechanism between cruciferin and glycinin is proposed, primarily driven by hydrophobic and specific electrostatic interactions.

Overall, these findings highlight cruciferin's potential as a clean-label modulator of plant protein aggregation. The mechanistic insights gained from this study can be employed to modulate the properties of cruciferin-legumin/glycinin aggregates, enabling the formation of clean label plant protein gels with improved functionality and consumer appeal.

Keywords:
plant proteins, soy, pea, rapeseed, protein aggregation, co-aggregation, denaturation, fractionation, protein interactions, clean-label

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Modification of pea albumin structure by pulsed electric field (PEF)

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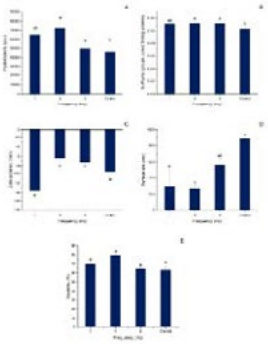
Pulsed electric field (PEF) is a non-thermal technology based on the application of short pulses of high voltage to biomaterials and has been used in several applications, such in the modification of macronutrient structure, for example, in proteins. In the food industry, PEF is used especially for vegetable proteins, due to its capacity to modify the vegetable protein structure and thus enhance its applicability in the food industry, especially plant-based products [1]. Among vegetable proteins, pea proteins have been gaining attention due to their advantages compared to other vegetable proteins, such as low water and land consumption, good amino acid balance, and high productivity [2]. However, most studies related to pea proteins and PEF do not specifically explore how each fraction is affected by PEF. Thus, this study aims to investigate the effect of PEF treatment on the structure of pea albumin and to assess how different PEF frequencies influence its structural behavior. For this purpose, a pea albumin solution (1% w/w, 91.71% protein, purity: 82% of albumin) was exposed to PEF treatment under an electric field strength of 15.6 kV/cm, with a pulse width of 5 μs and 30 pulses. The treatments were performed at frequencies of 1, 3, and 6 Hz in a batch-mode electroporation system developed by [3]. The specific energy input for all three samples was the same, 15.6 J/g. The samples were then subjected to electrophoresis, particle size, zeta potential, intrinsic fluorescence, hydrophobicity, free sulfhydryl groups, and solubility analysis. In SDS-PAGE, no differences were observed between the samples, showing that PEF did not cause alterations in the primary structure. After PEF, the intrinsic fluorescence for all the treatments increased compared to the control, and also a redshift from 337 to 344, 341.5, and 338 for 1 Hz, 3 Hz, and 6 Hz, which may be a reflection of structural alterations in the protein, including conformational rearrangement leading to the unfolding of the protein, until 3 Hz and aggregation at 6Hz. The increase in hydrophobicity is also correlated with protein unfolding. Compared to the control, the highest increase was observed for the frequency of 3 Hz, followed by 1 Hz, probably due to protein unfolding, which exposes hydrophobic residues that were hidden inside the protein. Regarding free SH groups, no difference was observed. Analyzing the particle properties, an increase in zeta potential can be observed at a frequency of 1 Hz and a reduction at other frequencies. A reduction in particle size was also observed, from 876.73 nm (control) to 536.98 nm, 297.47 nm, and 272.48 nm, for frequencies of 6 Hz, 1 Hz, and 3 Hz, respectively. The structural and particle changes allow for an increase in solubility, from 63.07% in the control to 80.07%, 69.37% and 64.65% respectively, for the frequencies 3 Hz, 1 Hz, and 6 Hz. Comparing the frequencies, even with the same energy input, it can be observed that the structural response for PEF is different. Probably the more frequent pulses (6 Hz) prevent the protein from reorganizing, promoting collisions and interactions between partially unfolded molecules, which results in aggregation and decreased solubility. Thus, it is possible to observe that PEF affects the pea albumin structure in a frequency-dependent way, and shows that PEF can be used to modify pea albumin, improving its functional properties and increasing its potential for use in plant-based food systems.



Effect of PEF treatment frequency on different properties of pea albumin. (A) Hydrophobicity; (B) Free sulfhydryl (SH) content; (C) Zeta potential; (D) Particle size; (E) Solubility. Data are presented as mean ± standard deviation (n = 3).

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Acid induced gelation of pea protein: impact of protein pre-treatment and post-fermentation processing on gel properties

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Plant protein-based acid-induced gels, such as yogurt alternatives, are gaining increasing importance. However, while previous research has primarily focused on gelation behaviour and, to some extent, on the effects of formulation and pre-treatment conditions, the influence of shear during post-fermentation processing—either alone or in combination with pre-treatment effects—has not yet been investigated.

Therefore, the aim of our study was to investigate the combined effects of protein pre-treatment at different pH-values and post-fermentation shearing on the final gel properties of pea protein gels. To this purpose, pre-aggregation was performed at pH 6, 7, and 8 to obtain aggregates with different solubilities, and consequently gels with distinct initial rheological properties [1] . After gelation, the gels were subjected to a sequence of shear treatments designed to simulate different processing steps: stirring (10 min at 1 s^{-1}), pumping (10 and 30 min at 100 s^{-1} and 500 s^{-1}), and dispensing (1 min at 800 s^{-1} and 1250 s^{-1}) [2] . Gel characterisation focused on the complex modulus |G*| and loss factor tan δ before shearing, immediately after shearing, and after a resting period of 60 minutes, as well as on gel strength A and coordination number z measured before shearing and after resting.

Results showed a significant effect of pre-treatment pH on the rheological parameters throughout the process. More specifically, increasing the pH during pre-treatment resulted in increased complex modulus |G*| and gel strength A after fermentation. Shearing as a whole decreased these parameters in all samples. However, no significant impact could be attributed to the specific variation of either shear rate or duration during the simulated stirring, pumping, or dispensing steps. Upon resting, partial restructuring of the gels occurred; however, the gel strength A remained markedly lower than before shearing in all samples. Interestingly, in samples pre-treated at pH 8, shearing followed by resting resulted in an increased loss factor tan δ and a decreased coordination number z compared to the original gel, whereas pre-treatment at pH 6 led to a slight increase in coordination number z. These observations indicate differences in shear-induced structural rearrangements depending on pre-treatment conditions and the initial gel structure.

Keywords:
rheological properties, yoghurt alternative, pre-aggregation, gel structure, post-fermentation processing

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Tuning the emulsifying properties of sunflower and olive protein hydrolysates by enzymatic treatment and pH

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This work investigates the influence of the enzymatic treatment (Alcalase or trypsin, degree of hydrolysis 5%) and pH (pH 7 or 4) on the interfacial and emulsifying properties of sunflower and olive protein hydrolysates. Independently of the enzymatic treatment, short peptides (1–3 kDa) were the most abundant in sunflower protein hydrolysates, whereas olive protein hydrolysates were richer in large peptides (>10 kDa). Peptides present in all hydrolysates gained in structure when adsorbing at the oil-water interface due to their facial amphiphilicity, with sunflower peptides presenting a more marked β-sheet conformation than olive peptides. Tryptic hydrolysates of both substrates showed higher interfacial adsorption compared to hydrolysates produced with Alcalase, especially at pH 4. All hydrolysates resulted in elastic interfaces, with generally higher values of dilatational complex modulus at pH 7 compared to pH 4. These findings correlated well with the higher emulsifying activity of all hydrolysates at pH 7 than pH 4. Particularly, sunflower protein hydrolysates led to stiffer and more solid-like viscoelastic interfacial layers than olive peptides due to increased interactions between β-sheet peptides at the interface. Indeed, the use of sunflower protein hydrolysates as emulsifiers resulted in 5 wt % oil-in-water emulsions with higher physical stability at both pH 7 and 4 when compared to olive protein hydrolysates.

Keywords:
Emulsifying peptides, oil-in-water emulsions, adsorption, dilatational rheology, synchrotron radiation circular dichroism, stability

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Pérez -Gálvez et al. Food Hydrocolloids 154, 110135, 2024.

RHEOLOGICAL BEHAVIOR OF ACIDIFIED GELS PRODUCED FROM FABA BEAN PROTEIN CONCENTRATES

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The current emphasis on plant proteins as substitutes for animal proteins, due to growing consumer demand for healthier foods and awareness of environmental issues, gives rise to a number of questions regarding the application of such proteins. Pulses, which are an important source of proteins, are very promising candidates and particularly, faba bean (Vicia faba L.) have been highlighted as a potential source in plant-based analogues such as acidified emulsions imitating dairy yogurts. Therefore, the principal aim of this study was to evaluate the rheological behavior of acidified emulsions produced from different faba bean protein ingredients obtained by dry fractionation. To this end, the first step was to perform chemical acidification (using glucono-delta-lactone) on soluble faba bean proteins and rheological analyses on acid gels formed by these soluble proteins at different concentrations for five different cultivars. Three varieties were then selected for the production and analysis of the rheological behavior of yogurt-like emulsions (4 wt.% total protein and 2 wt.% rapeseed oil). The formation of acid gels by soluble proteins indicated a proportional relationship between protein concentration and gel strength, which, in turn, depended also of the faba bean cultivar. The rheological behavior of acidified yogurt-like emulsions produced by pre-selected faba bean protein concentrates showed the formation of strong gels with much higher storage modulus (G') values (1330-2240 Pa) than the ones found for standard commercial dairy yogurt (200-400 Pa). However, these results highlight the potential of plant protein ingredients in the production of dairy analogues.

Keywords:
plant-based analogues, chemical acidification, functionality, acidified emulsions, rheology

Acknowledgements:
This work benefitted of the financial support of the French government through the National Research Agency (ANR) as part of France 2030 in the framework of LETSPROSEED ANR-22-PELG-002. The authors would like to thank Valérie Beaumal for her technical and analytical support.

Mechanisms Responsible for Gelation during High-Temperature Treatment of Whey Protein Aggregates

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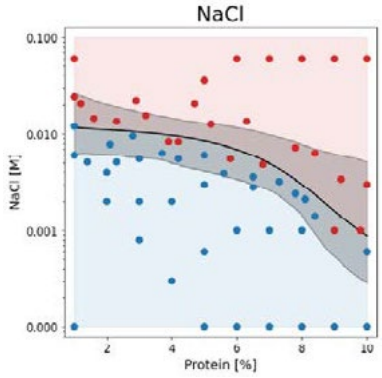
Whey protein nanogel particles are promising functional ingredients for beverage applications due to their lower viscosity dependence on protein concentration compared to other whey protein aggregates. This is of special interest for application in ultra-high temperature (UHT) treated beverages. However, the mechanisms governing interactions between the particles and with other food matrix components such as minerals during high-temperature processing remain uncharacterized, limiting control over their functional properties after processing.
In this study, phase diagrams were established for whey protein nanogel dispersions treated under UHT conditions (143 °C, 5 s), exploring the effects of protein and nutritionally relevant mineral concentrations. Dispersions in the transition region were studied using laser diffraction and confocal laser scanning microscopy (CLSM) to assess structural modifications post-treatment. CLSM revealed spherical particles with consistent morphology and size, with some aggregated particles present after UHT treatment. These observations were supported by laser diffraction data, and no changes in the overall single-particle structure were observed in dispersions that remained liquid.
Temperature-dependent structural development was further investigated by diffusing wave spectroscopy (DWS) during heating up to 150 °C. Dispersions with varying mineral concentrations exhibited a transition from liquid-like to solid-like behavior at a mineral concentration-dependent temperature, with structural rearrangements becoming more pronounced with prolonged heating and subsequent cooling. Visual inspection confirmed flocculation at higher mineral concentrations after the temperature cycle.
Additionally, UHT treatment led to an increase in non-native peptide crosslinks formed via a dehydroalanine intermediate, as quantified by liquid chromatography-mass spectrometry. These results correlate with the DWS observations, confirming that structural changes and network formation in the dispersions are strongly dependent on temperature. This indicates that an energy barrier exists for the gelation of the dispersed whey protein nanogel particles.
Collectively, these findings advance the mechanistic understanding of gelation in whey protein nanogel systems under processing-relevant conditions. This knowledge supports the design of protein-rich beverages subjected to high-temperature processing.

Keywords:
whey protein aggregates, UHT treatment, minerals, phase diagrams, gelation, colloidal stability, pH, heat treatment, thiol reactions



Phase diagram of β-lg nanogel particle dispersions after UHT treatment as a function of protein and an added NaCl. Red points represent a gel, and blue points represent a liquid. The grey area represents a 95 % confidence interval for the boundary.

Designing and Understanding Thermoresponsive Shape-Shifting in 4D-Printed Pea-Based Foods and its Applications

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Food 3D printing, also known as additive manufacturing, has created new opportunities for designing reconfigurable food structures. When time is introduced as an additional dimension, printed constructs can be programmed to undergo shape-morphing transformations, a concept known as 4D printing. However, achieving precise and reproducible deformation in plant-based systems, elucidating the underlying mechanisms, and translating them into real-world applications, remains a significant challenge. In this study, we developed a high-concentration pea-based suspension tailored for 4D printing and systematically examined the influence of printing parameters (print size, infill density, and printing path) and processing conditions (heating temperature and duration) on controllable shape transformations. Rheological tuning reveals that water content governed extrudability and structural integrity. By varying baking temperature, duration, and path design, we demonstrated how these factors interact to regulate bending magnitude and direction. A key mechanism is proposed: nonuniform vapor expansion within the printed matrix generates internal stresses that drive bending aligned with the print trajectories. To validate design principles, edible prototypes such as bending plates and floral actuators are fabricated and successfully actuated under conventional baking. These results demonstrate that programmable shape changes in plant-based foods are feasible, and offer a route for designing functional, responsive food constructs with controllable morphology.

Keywords:
Keywords: 3D/4D printing, shape changing, thermoresponsive deformation, pea-based suspension

Heat-induced aggregation of faba bean proteins: influence of heating temperature and protein concentration on induced molecular interactions

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Faba bean (*Vicia faba* L.) proteins are promising sustainable alternatives to animal proteins in food applications. During a typical wet isolation process to generate faba bean protein ingredients, a heat treatment is applied to *i.a.* reduce the microbial load. However, the impact of such heating step on the protein dispersibility remains poorly understood, particularly in terms of the underlying aggregation mechanisms that are induced during isolation. A key, yet often overlooked, factor in this regard is the protein concentration during heating, which in lab scale processes is often low, but much higher (>10%) in industrial processes. How protein concentration modulates the balance between different molecular interactions governing heat-induced aggregation has not yet been systematically investigated. Therefore, this study aimed to gain mechanistic insight into the nature of heat-induced aggregation of faba bean proteins by systematically investigating the influence of heating temperature (60, 80, 100 °C for 15 min) and protein concentration (2% and 12% w_p /v) on heat-induced aggregation of faba bean proteins during their isolation via aqueous extraction (pH 7.0) and isoelectric precipitation (pH 5.0). The heat treatment was performed on the protein pellet following isoelectric precipitation, after redispersion in water and pH adjustment to 7.0. After subsequent freeze drying, the characteristics of the different obtained protein isolates were further studied.

At 2% w_p /v, heating did not reduce protein dispersibility of the isolate, but dispersible aggregates were formed. In contrast, at 12% w_p /v, protein dispersibility of the isolate decreased strongly with increasing temperature (from 76.7 ± 0.1% for unheated samples to 26.9 ± 10.7% after heating at 100 °C). Confocal microscopy showed that protein aggregates were larger after heat treatment at 12% w_p /v than at 2% w_p /v. Size-exclusion HPLC after extraction in media containing different bond-breaking chemicals confirmed that aggregation via disulfide bonds always occurred, regardless of the heating temperature and concentration. Surface hydrophobicity and free SH-group measurements showed that, at high protein concentration, hydrophobic interactions became more dominant, leading to the formation of large, non-dispersible protein aggregates. These findings illustrate that at higher protein concentrations, non-covalent aggregation is the main driver of the reduced protein dispersibility during heat treatment as part of faba bean protein isolation.

Taken together, the results show that while disulfide bonds always form during heating, contributing to the formation of dispersible aggregates, protein concentration governs the extent of non-covalent aggregation, and consequently the loss of dispersibility in faba bean protein isolates. These results provide strategies for minimizing dispersibility losses during protein isolation, for instance by adjusting the protein concentration and/or by preventing the formation of non-covalent interactions.

Keywords:
Faba bean, protein isolation, heating, aggregation, molecular interactions

Protein aggregate oleogels: effect of aggregate properties on oleogel texture.

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Solid fats are essential for the texture of many food types. However, due to their high amount of, saturated fats, their use is discouraged, whereas the use of vegetable oils, higher in health-promoting unsaturated fats, is promoted. However, as oils are liquid, they often cannot provide the needed textural properties. To combine a more healthy composition with solid-like characteristics, oleogels have received attention in recent years. Oleogels consist of a continuous oil phase with a gelling agent. Among those gelling agents are proteins, which have been shown to create a space spanning network by attractive hydrophilic interactions between protein aggregates. To strengthen the network, water can form capillary bridges between the aggregates, increasing the gel strength.
In literature, it has been shown that for model silica particles, the particle properties, such as size, can affect the final gel network. In the case of protein aggregates, also properties as density, porosity, roughness or swelling capacity may be relevant. However, it is not clear how such properties can affect the final oleogel characteristics. To investigate this, whey aggregates where prepared at different pH values, which is known to change particle properties such as density and roughness.
The oleogels created with these protein aggregates (before addition of water) contained different protein concentrations, due to differences in protein interactions during the preparation process. Clear differences in the rheological properties, such as the gel strength and critical strain, were observed, indicating that such properties indeed play an important role. For example, oleogels prepared with protein aggregates created closer to the iso-electric point, being denser and rougher, showed a lower degree of interactions, leading to a higher protein content and a lower critical strain.
When water was added to increase protein interactions, differences in gel strength and critical strain decreased. This emphasizes the large influence of capillary bridges on this type of oleogel.
In this presentation, we will discuss how such protein oleogels can be created, and how specific rheological characteristics depend on the specific protein aggregate characteristics, the interactions, and the particle network formation. These results can be used to create oleogels with tailored characteristics, by altering the properties of the aggregates and the type of gel that is formed. These oleogels can be used to provide healthy alternatives to solid fats with a variety of textures.

Deciphering Acidulant-Mediated Gelation of Hybrid Systems through Advanced Imaging and Rheology

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Integrating plant proteins via partial substitution of dairy components is a pivotal strategy for enhancing global protein supply and achieving substantial environmental mitigation. However, this substitution introduces complex technological challenges rooted in the microscale physicochemical interactions that ultimately govern the macroscopic functionality of hybrid systems. A critical knowledge gap persists regarding the mechanistic understanding of how diverse ingredients interact with one another. To address this, an integrated approach of synergistically combining Super-Resolution Microscopy and Coherent Anti-Stokes Raman Scattering were employed with quantitative image analysis and dynamic rheology to elucidate the microstructural dynamics of gelation in a hybrid system as influenced by different acidulants. Cross-correlation analysis of the resulting images quantified inter-protein interactions and revealed distinct patterns of structural organization, with rheological properties directly correlated with the high-resolution imaging data. The work unequivocally demonstrated that the synergistic integration of advanced imaging is paramount for overcoming the knowledge gap in complex hybrid systems. The findings generated reveal and exploit the underlying microstructural architectures, directly facilitating the rational engineering of sustainable, next-generation food products with precisely optimized functional performance.

Keywords:
Hybrid Systems; Super-Resolution Microscopy; Coherent Anti-Stokes Raman Scattering; Rheology

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Recent Developments in Electrospraying Assisted by Pressurized Gas for the Encapsulation of Challenging Bioactives

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This presentation will showcase several recent advancements developed within our research group, focusing on the use of high-throughput Electrospraying Assisted by Pressurized Gas (EAPG) for the encapsulation and drying of challenging bioactive compounds. This proprietary and innovative technology, introduced and patented by our team, relies on the atomization of a polymer solution containing the bioactive compound via a pneumatic injector. Compressed air is used to nebulize the solution within a high-intensity electric field. During this process, solvent evaporation occurs at room temperature inside an evaporation chamber, resulting in the collection of the encapsulated material as a free-flowing powder. Compared to conventional encapsulation methods, EAPG offers multiple advantages. It is a gentle, room-temperature process that preserves the integrity of sensitive compounds. It produces free-flowing particles with narrow size distribution, high encapsulation efficiency, exceeding 95%, without compromising the functional properties of the bioactives. It is highly versatile, accommodating a wide range of bioactive compounds and encapsulating materials. To date, this technique has been successfully applied to encapsulate complex bioactives such as omega-3 fatty acids, underutilized polyphenols and probiotics into various polymeric matrices, including water-soluble and gastroresistant materials. Accelerated oxidation tests confirmed the enhanced stability and extended shelf life of the encapsulated products. Furthermore, the process has been scaled up to meet industrial demands, achieving production rates of several kilograms per hour while maintaining the quality and characteristics of the encapsulated materials. The case studies presented here highlight the potential of EAPG technology as a scalable and efficient solution for the industrial delivery of challenging bioactive compounds, particularly in the development of functional food applications.

Keywords:
EAPG, omega-3 fatty acids, polyphenols, probiotics, encapsulation, industrial scale, functional foods.

Acknowledgements:
This research was funded by H2020 EU projects CAPSULTEK (reference number 873827) and FODIAC (reference number 773872), the V Catedra Agrobank Award, Despega IATA (8DI221) and Ayudas a los Científicos Titulares de acceso libre OEP 2020-2021 (2024ICT225).

Encapsulation of emulsions in monodisperse alginate capsules: a high-throughput droplet millifluidics approach

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Microfluidics is a well-established emulsification technique to produce complex liquid multiphase systems with high accuracy [1] . By adding a phase changing step to the process, even structured systems such as core-shell capsules with a liquid core and a gelled shell can be achieved [2] . A formulation based on biopolymers turns these capsules into interesting candidates for a wide range of application in life science related research and industries [3] . However, it remains a challenge to overcome the gap between process specific and formulation related limitations and the requirements set by an application in food production. This industry commonly requires high mass flows and convenient process set-ups, whereas microfluidics is known for its limitations regarding throughput and process stability over time.
Therefore, this research focuses on developing and adapting a microfluidic process based on a glass capillary device so that it is capable of producing significant amounts of alginate-based core-shell capsules with high accuracy. It explores the interplay between increased capillary diameters and adjusted formulation parameters, along with their impacts on process stability and product properties, at the interface between micro- and millifluidics.
As a result of this study, millimeter-sized core-shell capsules, consisting of a liquid water-in-oil emulsion core and a gelled calcium alginate shell, were produced, see Figure 1. In a coaxial glass capillary system, the two immiscible liquid phases formed a ring stream from which droplets periodically detached. The vertical alignment enabled the formation of large droplets in ambient air, the aqueous shell was furthermore gelled externally in reactant solution. The process was controlled by the orifice size of the outer capillary, fluid flow rates and alginate concentration. The optimized parameters were process stability over time, maximum achievable volume flow rates, droplet size and droplet size homogeneity, and core-shell ratio.
The developed process can be used to produce novel encapsulation systems for foods at relatively high throughputs. Stable production of spherical, monodisperse capsules with controlled product properties were achieved at up to 240 ml/h in dripping regime with nearly 100 % encapsulation efficiency. Furthermore, the influence of the gelation step on capsule size and loading capacity was elucidated and a developed model predicted the final properties with an accuracy above 97 %. The findings of this study confirm the ability of in-air millifluidics to efficiently encapsulate inner phase of variable viscosity by creating structured particles with precisely controlled attributes like core diameter, shell thickness and shell hardness.

Keywords:
alginate hydrogels, emulsion, core-shell capsule, co-flow

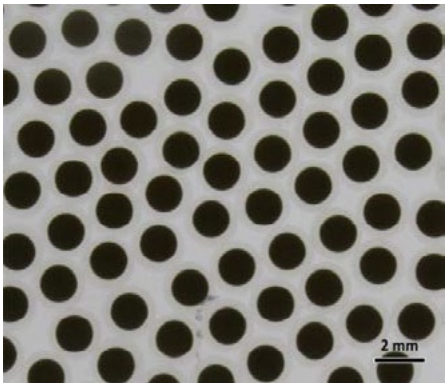

Figure 1: Monodisperse milli-capsules with a gelled alginate shell and a liquid water-in-oil emulsion core

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Acknowledgements:
PROMOS: financial support for travelling and living expenses of Johannes Marburger during his research stay at Loughborough University. International Excellence Fellowship of KIT: financial support for the research stay of Goran Vladisavljević at KIT.

POSTER COMMUNICATION

Effect of oil type on the stability of plant-based O/W emulsions

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Recent trends in the food industry highlight a growing consumer expectation for food products that offer more than basic nutrition. The modern consumer considers food as a key determinant of health, thus necessitating a focus on enhanced nutritional value and functional benefits in product formulation [1]. The growing demand for healthier and more sustainable food products has driven the use of plant-based ingredients. In this sense, plant proteins, particularly from chickpeas, offer excellent nutritional value and functional properties, making them ideal as emulsifiers [2, 3]. Furthermore, the health benefits of food products would increase if health-promoting specialty oils were used. These oils are valued not only for their nutritional role as fats, but also for their bioactive compounds, as they are typically rich in components such as omega-3 fatty acids, phytosterols, tocopherols, carotenoids and other minor lipids, which have antioxidant, anti-inflammatory and cardioprotective effects [4]. This work evaluates the stability of O/W emulsions stabilized by chickpea protein, comparing the effect of three different specialty oils: chia, walnut and sesame. Emulsion stability was assessed through measurements of droplet size distribution and light scattering, which were then correlated with interfacial properties, measured in a droplet tensiometer and interfacial shear rheology. The results demonstrate that chickpea protein successfully stabilizes emulsions containing all three oils.However, the type of oil significantly impacted stability. In this sense, although chia oil/w emulsions showed good stability against emulsion destabilisation phenomena, interfacial shear rheology revealed a higher response for walnut oil systems. Conversely, a reduction in interfacial dilatational rheological properties over time for the walnut oil systems was also observed, which could lead to a potential destabilisation of emulsified systems. Furthermore, both dilatational and interfacial shear rheology measurements predict that sesame oil is the most vulnerable to destabilisation processes. This study highlights how the specific fatty acid profile and minor components of each oil directly influence the interfacial properties and overall stability of plant-protein-stabilized emulsions.

Keywords:
DSD; Dilatational; Emulsions, Healthy oil; Interfacial; Rheology, Shear

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Acknowledgements:
This research has been funded by FEDER / Ministerio de Ciencia e Innovación - Agencia Estatal de Investigación through the MCIN/AEI/10.13039/501100011033 / FEDER, UE, through the project PID2022-142663OB-I00 project.

High internal phase emulsions stabilized by pulse proteins and their complexes with pectin: relating 2D interfacial rheology to 3D bulk rheology

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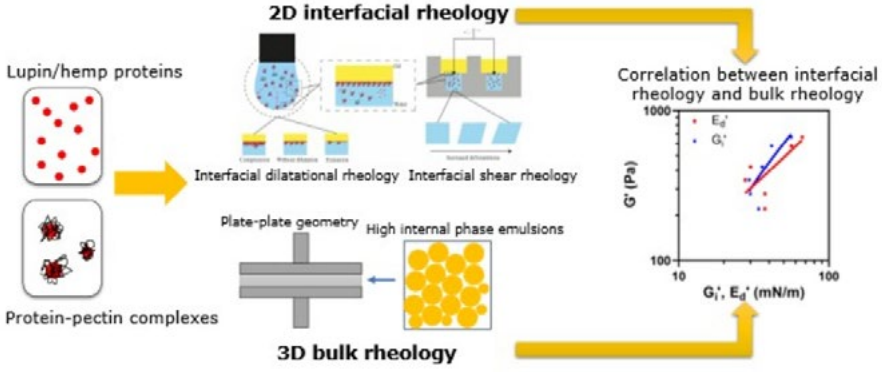
High internal phase emulsions (HIPEs) are emulsions with an oil volume fraction above the maximum packing limit. Interfacial rheological properties affect the bulk shear properties of HIPEs, as the deformation of closely-packed oil droplets causes deformation of interfaces of the oil droplets. Which interfacial properties dominate the bulk shear response will depend on the applied shear strain. The interfacial shear and dilatational rheology of lupin and hemp proteins, and lupin or hemp protein-pectin complex stabilized oil-water interfaces were studied in both the linear viscoelastic (LVE) and non-linear viscoelastic regimes (NLVE). The rheological properties of HIPEs were characterized by both steady shear rate tests (0.03-100 s^{-1}) and dynamic rheological tests (shear strain sweeps, with strains 0.01-1000%). In the LVE regime, a positive correlation between both the interfacial shear modulus (G_i') and dilatational elastic modulus (E_d'), and the bulk shear elastic modulus (G') of HIPEs was found. At strains in the NLVE regime (30% strain), only E_d' was positively correlated with G', while G_i' only had a marginal effect on G'. This is the result of the strong strain dependence of G_i'. Finally, we developed a model to relate E_d' and G_i' of oil-water interfaces to G' of HIPEs, based on the interfacial momentum balance which can explain this dependence of G' on both interfacial parameters. Our work provides a more fundamental understanding on how surface rheological properties affect the rheology of HIPEs.

Keywords:
Pulse proteins, pectin, electrostatic complex, interfacial rheology, bulk rheology, high internal phase emulsion, model linking 2D-3D rheology



Graphical abstract of the oral presentation

Rheology and tribology of dextran/ polyethylene oxide-based water-in-water emulsions

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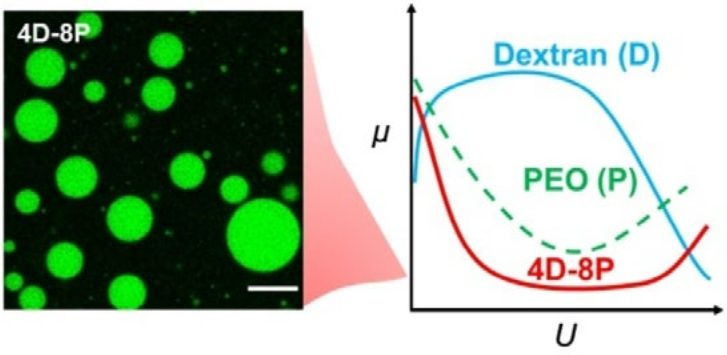
Water-in-water (W/W) emulsions, derived from phase-separating mixtures of hydrophilic macromolecules, have attracted a great deal of attention for encapsulation, drug delivery, biotechnical separation and the development of stable 'oil-free' emulsions. Although their formation and stabilisation mechanisms have been studied in depth, evaluation of their unique rheological and tribological performance remains in its infancy. This study aimed to investigate the microstructural, rheological and tribological properties of model W/W emulsions composed of dextran (D) and poly(ethylene oxide) (P) at a fundamental level. Rheological analysis revealed that pure D exhibited pronounced shear-thinning behaviour compared to pure P. For D-P W/W emulsions, increasing the P concentration [P] resulted in increased viscosity (η), whilst increasing the D concentration [D] intensified shear-thinning behaviour, likely due to changes in the quantity and size of D-based droplets. Confocal laser scanning microscopy (CLSM) demonstrated a significant increase in the average droplet size with higher [D] or [P]. A striking tribological result was that the W/W emulsions demonstrated an unusually flat mixed lubrication regime, with friction coefficients (m) < 0.01 over a considerable range of sliding contact speed (~10 to 100 mm s^{-1}, of physiological relevance) before the onset of the elastohydrodynamic lubrication (EHL) regime. This was quite unlike the behaviour demonstrated by solutions of the individual polymers on their own. Such concentration-dependent behaviour was attributed to W/W emulsion droplets entering the tribological gap, flattening and reducing the viscosity of the entrained lubricants, thus delaying the formation of a fluid film. Overall, this detailed study shows how fabrication of W/W emulsions via phase-separating polymers can offer unique lubrication characteristics that could provide advantageous aqueous lubricants for biomedical applications.

Keywords:
Water-in-water emulsion, tribology, droplets deformation



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Acknowledgements:
The author CW acknowledges the funding from China Scholarship Council (CSC NO. 202306790025).

Exploiting the Multi-Functionality of Pectins in Food Systems

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Pectin is a naturally occurring polysaccharide present in most plants. Pectins are mostly extracted from citrus or apple, and are widely used in food products where they perform as thickeners, stabilizers, or gelling agents. Unlike common food hydrocolloids, pectins are well-perceived by consumers, and are increasingly found in fruit products, confectionary or acidified dairy products, but also in pharmaceutical applications or in cosmetics [1-4] . The structure of pectins is very complex and is closely related to its properties. For example, the degree of methoxylation (DM) impacts the gelling mechanism of pectin and the final gel macroscopic properties. [5, 6] DM also affects the interactions between pectin and proteins and, ultimately, the stabilization of protein aggregates under acidic conditions. [7, 8] We found that rationale selection of pectin polysaccharides based on their structure enabled the design of novel systems, outside of the classical functionality of pectins in food products. The relationship between the fine structure of pectin and the physico-chemical properties of the final formulations was systematically studied, and was correlated to sensory attributes. This work demonstrates that careful consideration of pectin structure enables novel formulations using this well-known hydrocolloid.

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Using large amplitude oscillatory shear (LAOS) to unravel the structure of emulsion-filled pea protein gels: Effects of high-pressure homogenization

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Commercial pea protein isolate (cPPI) often exhibits poor thermal gelation due to denaturation history. Our previous study revealed that high-pressure homogenization (HPH) effectively improved cPPI's thermal gelation properties by decreasing its aggregate size and dispersibility **in water** [1]. However, the impact of HPH on cPPI's thermal gelation properties **in oil-in-water** emulsion remains **underexplored** . Therefore, we investigated how HPH affects thermal gelation in cPPI-stabilized emulsions prepared with various levels of non-crystallizable (sunflower) or crystallizable (coconut) oil using the advances in large amplitude oscillatory shear (LAOS).

We prepared homogenized or unhomogenized (8.5% w/w) cPPI-stabilized emulsions with 0, 10, and 20% w/w of either sunflower oil or coconut oil (Figure 1). We performed temperature sweeps followed by LAOS and conducted in-depth LAOS analyses using both Fourier Transform Coupled with Chebyshev Coefficients (**FTC**) and Sequence of Physical Processes (**SPP**).

Temperature sweeps showed that in unhomogenized emulsion-filled protein gels (EFGs), 10% dispersed phase slightly increased final G′, suggesting weak interactions with small, dispersible protein aggregates (a minor fraction in cPPI [1]), causing the dispersed phase to act as active fillers. At 20%, G' dropped sharply, suggesting these interactable aggregates may have been insufficient to accommodate the excess interface. Thus, it can be assumed that the dispersed phase acts as active or inactive fillers depending on loading. In homogenized EFGs, however, G′ increased with increasing dispersed phase, indicating droplets consistently act as active fillers, presumably because of more small, dispersible protein aggregates upon HPH treatment. FTC analysis indicated that in homogenized EFGs, energy was dissipated more gradually with increasing dispersed phase. Weak strain overshoot occurred concurrently with an increase in the positive shear-thickening ratio by increasing dispersed phase, suggesting that active fillers promote the formation of temporary network during oscillation. SPP analysis revealed that in homogenized EFGs with 20% w/w dispersed phase, sunflower oil droplets may be ruptured from the matrix upon deformation, leading to stronger structural breakdown and subsequent restructuring. By contrast, crystallized coconut oil droplets may limit the motion of its local networks, enhancing resistance to deformation but reducing restructuring. This difference may mainly come from the crystallization ability of coconut oil.

Our investigation highlights (i) the strong effectiveness of HPH in shifting dispersed-phase—matrix interactions toward active fillers, and (ii) the value of LAOS analyses for revealing structure evolution and structural differences between sunflower oil and crystallized coconut oil EFGs.

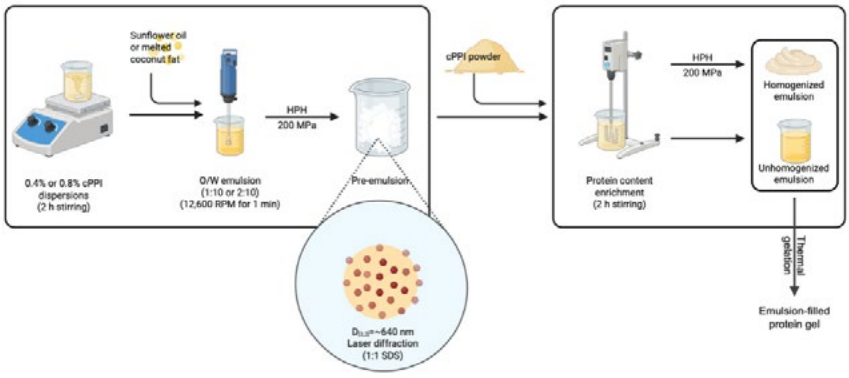

Figure 1: Schematic representation of sample preparation.

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Acknowledgements:
Yadong Li is a Doctoral Researcher funded by KU Leuven Internal Funds.

Design of Dairy-Free Custard Using Alphitobius diaperinus Protein as a Structuring Agent

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The visual appearance of edible insects remains one of the major obstacles for consumers in Eastern Europe. As a strategy to improve acceptance, the use of insect-derived ingredients has been implemented as a sustainable and less perceptible alternative in food formulations. In this work, *Alphitobius diaperinus* (AD) protein isolates were used to develop a lactose-free creamy custard analog. Larvae were starved for 48 h, thermally treated (100 °C, 1 min), dried (40 °C, overnight), ground, and defatted to obtain insect flour. Proteins were extracted by conventional alkaline solubilization (1:10 ratio, pH 10), followed by acid precipitation, dialysis, and freeze-drying. Primary emulsions were prepared by homogenizing preheated protein solutions (3, 5, and 8 %) with rapeseed oil (7500 rpm, 3 min). Subsequently, gelatin solutions (3 %) were added and homogenized to form the final emulgels (primary emulsion: gelatin solution, 1:1), which were allowed to stand at room temperature and then stored under refrigeration for further analyses. The obtained protein isolates (77 % true protein) exhibited a biological value comparable to pea and rice proteins (~64), with lysine identified as the limiting amino acid. Increasing AD protein concentration led to a progressive rise in firmness (from 0.28 ± 0.02 N in the control to 0.51 ± 0.03 N at 8 %), water-holding capacity (from 94.19 ± 0.27 % to 98.96 ± 0.16 %), and particle size (Dx (50) from 2.97 ± 0.03 μm to 6.22 ± 0.13 μm). Conversely, the whiteness index decreased (from 88.84 ± 0.06 to 76.06 ± 0.23), indicating a darker appearance with higher protein content. Overall, the incorporation of AD protein isolates improved the structural and functional properties of the lactose-free custard analog, supporting their potential as sustainable ingredients in high-protein, dairy-free desserts.

Keywords:
Lesser mealworm, protein isolate, emulgels, custard analog

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Acknowledgements:
This research was funded by European Union's Horizon 2020 Research and Innovation Program under grant agreement No. 952594 (ERA Chair project DRIFT-FOOD).

Hybrid dietary fiber gels

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Hybrid gels composed of different dietary fibers offer promising functionalities for food structuring. This study explores the microstructure and rheological properties of mixed gels with different types of dietary fibers. The characterization of the structural organization and flow behavior of these hybrid gels is done using confocal laser scanning microscopy (CLSM) and rheology. The focus of the study is how the average molecular weight of dietary fiber modulates gel network formation, stiffness, and viscoelasticity. Furthermore, we investigate the stability of the gels against syneresis and/or sedimentation. This work contributes to the development of health-promoting food formulations.

Keywords:
Hybrid gels, dietary fiber, microstructure, rheology

Patchy particles as a model system to understand protein aggregation

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We investigated the structure formation in synthetic and protein model colloidal particles. As synthetic model particles we use di-patch and tetra-patch colloids to model the specific bonding of molecules. We employ critical Casimir forces to achieve tuneable attraction and add sucrose to the binary solvent to reach density matching. We find that the patchy particles form a 3D network and are well distributed in space even on a long timescale. By locating and tracking the particles in 3D we can reconstruct the system and understand cluster alignment and growth.
We also study network formation using whey protein microparticles as the experimental system. In this model system, the proteins are pre-clustered in micrometre-sized colloidal proteins, and aggregation is followed in 3D space upon lowering the pH to obtain insight into protein gelation for food applications.

Keywords:
Protein aggregation, microparticles, patchy particle, shear-induced gelation

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Protein emulgels enhanced by low intensity pulsed electric field (PEF) pre-treatment

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The development of greener technologies for food ingredient processing aims not only to enhance product functionality but also to reduce environmental impact. Pulsed electric fields (PEF) represent a promising non-thermal and chemical-free processing technique capable of increasing cell membrane permeability, facilitating compound release, and inducing structural modifications. In this study, the effect of PEF-assisted extraction of fibrous protein (gelatin) from antelope (eland) skin residues on the rheological and physicochemical properties of gelatin-based emulgels designed to mimic spreadable products was investigated. The conventional extraction involved alkaline treatment (2% Ca $(OH)_2$) followed by thermal extraction at 60 °C for 6 h. In the PEF-assisted process, the alkaline step was replaced by low-intensity PEF pretreatment at 1 kV/cm (sample A) and 2 kV/cm (sample B), thereby eliminating the need for chemical reagents and reducing residue generation. Primary emulsions containing sunflower oil (20, 30, and 40%) and lecithin were prepared, and solubilized gelatin (1%) was subsequently incorporated to form emulgels. PEF pretreatment enhanced both large and small deformation properties in comparison to control samples. Gel strength increased from 0.06 N (control) to 0.11 N and 0.13 N for samples A and B, respectively. The storage modulus (G′) rose from 201 Pa to 423 Pa and 533 Pa, while gelling time decreased from 16 min to 9 min and 8 min. Color analysis showed darker gels with increased red and yellow chromaticity for PEF-treated samples. Emulgel hardness increased with oil concentration, and PEF-treated samples (0.30–0.37 N) exhibited firmer textures than the control (0.21 N), approaching the structure of commercial spreadable cheese (0.44 N, ~40% fat). Overall, PEF-assisted extraction improved gelatin functionality while eliminating the use of alkaline or acid treatments, reducing residue generation, and enabling the development of sustainable emulgels with desirable spreadable properties.

Keywords:
Pulsed Electric Field (PEF), eland gelatin, emulgels, spreadable system

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Acknowledgements:
This research was funded by European Union's Horizon 2020 Research and Innovation Program under grant agreement No. 952594 (ERA Chair project DRIFT-FOOD).

Influence of hydrocolloid interactions on gluten free bread quality parameters through response surface methodology

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Gluten-free bread remains technologically challenging because the absence of the viscoelastic properties of gluten weakens gas retention, limits expansion during proofing, and accelerates crumb firming during storage, meaning that hydrocolloids are often required to reinforce the starch-protein matrix and control water distribution throughout baking and shelf life in gluten-free breads. However, despite many commercial formulations, there is still limited systematic understanding of how individual and combined hydrocolloids should be added to optimise loaf volume, crumb texture and staling behaviour for specific gluten-free recipes. A market research study was conducted and found that of the 111 gluten-free breads, all contained at least one hydrocolloid. Modified cellulose, psyllium, xanthan gum and guar gum were the most frequently incorporated into formulations, either individually or as a blend with other hydrocolloids.
This study therefore investigated the effects of varying levels, (0-2 g/100g flour), of hydroxypropyl methylcellulose (HPMC), pectin and guar gum on the quality of gluten-free bread using response surface methodology (RSM). The RSM was applied to a pre-determined control gluten-free bread recipe to evaluate the interaction effects of the three hydrocolloids based on the analysis of specific volume, bread texture, cell size and moisture loss. Quadratic models showed significant individual and interactive effects of all three gums on specific volume and hardness. After analysing 30 recipes, numerical optimisation indicated that breads produced with intermediate levels of HPMC and guar gum and low pectin levels achieved higher specific volume and a softer more complete crumb structure. Pectin was found to increase the hardness of breads when added at over 1g/100g flour. HPMC when used at intermediate and higher levels was found to reduce the occurrence of large holes in the breads. After the RSM a final bread consisting of 1% HPMC, 0.1% guar gum and 0.25% pectin achieved a specific volume of 3.28ml/g and a hardness of 3.13N. This bread was greatly improved compared to the control bread consisting of no hydrocolloids with a specific volume of 1.93ml/g.
This study demonstrates the beneficial effects of hydrocolloids on gluten-free bread formulations and that RSM can be a useful tool for guiding hydrocolloid optimisation in gluten-free bread formulations.

Keywords:
Hydrocolloids, Gluten-free, Response Surface Methodology

Development of novel Pickering stabilizers from enzymatically treated lupin byproducts for stabilizing O/W emulsions

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The use of additives in processed foods has raised growing concerns regarding public health. Among these additives, emulsifiers and surfactants are widely employed in the cosmetic, pharmaceutical, and food industries. However, some synthetic food additives have been linked to adverse health effects, limiting their use across various industrial applications. Consequently, there is a pressing need to develop innovative solutions that can replace commonly used synthetic emulsifiers with natural and safe alternatives.

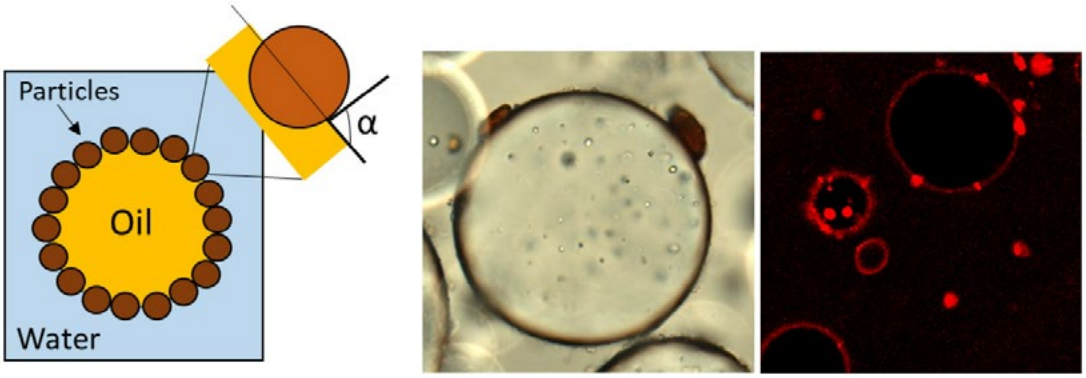
To address this challenge, the present study aims to advance the understanding of food-grade Pickering stabilizers (used as natural emulsifiers) derived from agri-food byproducts, and to evaluate new technological strategies for their production. In particular, this work investigates the application of enzymatic treatments to generate particle-based emulsifiers with enhanced surface activity, offering an opportunity to valorize agri-food residues while promoting circular economy principles and environmental sustainability.

In this study, Pickering emulsifiers were produced from lupin byproducts using an enzyme cocktail designed to reduce particle size and improve their affinity for the oil–water interface. The resulting particles were evaluated as potential colloidal stabilizers, and emulsions were formulated using different particle concentrations (0.5–5% w/w) and a fixed oil concentration (10% w/w). Emulsification was carried out through high-speed homogenization followed by microfluidization, and the resulting emulsions were characterized in terms of microstructure, creaming index, and Turbiscan stability.

Preliminary results showed that enzymatic treatment significantly enhanced the emulsifying properties of the particles. Emulsions stabilized with enzymatically treated particles exhibited greater stability and smaller droplet sizes compared with those prepared with untreated particles, indicating improved interfacial performance. They also displayed strong resistance to creaming, as confirmed by both the creaming index and the Turbiscan stability index, which varied depending on particle concentration. Confocal microscopy further demonstrated the adsorption of Pickering particles at the O/W interface, supporting their role in Pickering-type stabilization.

Overall, these findings offer valuable insights into the development of novel food-grade colloidal particles with enhanced emulsifying properties. The resulting Pickering stabilizers show strong potential for the formulation of innovative emulsion-based food products, contributing to a reduced reliance on synthetic additives.

Keywords:
Pickering emulsions; Agri-food byproducts; Lupin byproducts; Enzymatic treatment



Schematic representation of Pickering emulsions and images of microstructure

Acknowledgements:
This research was supported by ANID through Project FONDECYT-REGULAR Project N° 1240824

Characterization and utilization of hydrocolloid-structured emulsion-filled gels as alternatives to animal fat

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Emulsion-filled gels stabilized by various hydrocolloids have recently gained attention as potential candidates for fat replacement in food products. In this study, four hydrocolloids with distinct viscosity characteristics were used to formulate emulsion-filled gels and assess their applicability as substitutes for animal fat. Samples prepared with konjac and LBG exhibited markedly greater viscosity and viscoelastic properties than those containing agar or HPMC. Microstructural observations showed that the high-viscosity konjac and LBG emulsions produced notably smaller oil droplets. When incorporated into low-grade beef cuts through injection, the gels produced an appearance comparable to beef tallow-injected meat and contributed to enhanced tenderness. Among the hydrocolloids tested, HPMC-based gels displayed the greatest hardness and cooking loss after cooking, whereas konjac gels yielded the lowest cooking loss. Overall, hydrocolloid-stabilized emulsion-filled gels show promise as functional alternatives to animal fat in the improvement of low-quality food products.

Acknowledgements:
This work was supported by the Korea Institute of Planning and Evaluation for Technology (IPET) in Food, Agriculture, and Forestry (RS-2024-00509810)

Water-in-Oil Emulsions Stabilized by γ-Oryzanol Crystals

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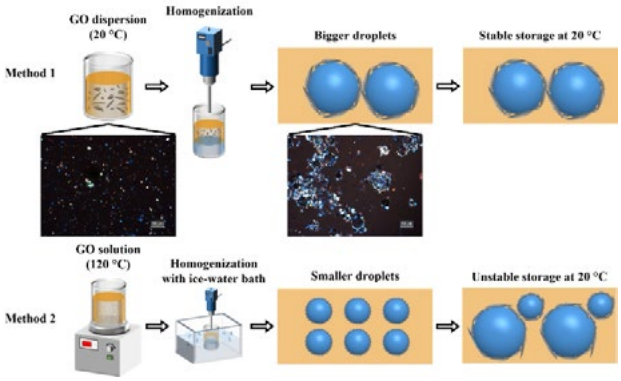
Water-in-oil (W/O) emulsions, in which water is dispersed in a continuous oil phase, are widely applied in food products, such as margarine, butter and chocolate fillings. To enhance their stability, low molecular weight (LMW) surfactants are commonly used as emulsifiers. In food applications, mostly sorbitan esters (Span), polyglycerol polyricinoleate (PGPR) and mono- and diacylglycerols (MAGs-DAGs) are used. However, biopolymers and particles from natural sources (e.g., modified lignin and starch, ethyl cellulose, phytosterols, cocoa butter) have aroused the interest of researchers because of their long-term stabilization. However, using sustainable, environmentally friendly particles to effectively stabilize W/O emulsions is still challenging for the food industry. In this framework, γ-oryzanol (GO) particles provide potential as emulsion stabilizing particles. GO is extracted from rice bran oil and contains a mixture of compounds formed through the esterification of ferulic acid and a triterpene alcohol or sterol. Meanwhile, there are no studies reporting W/O emulsions stabilized by γ-oryzanol only so far. Therefore, water-in-oil emulsions were prepared by directly dispersing GO in canola oil before emulsion preparation and characterized with polarized light microscopy (PLM), cryo-SEM and pfg-NMR. Stable W/O emulsions were prepared by dispersing 5% (w/v) GO in the oil phase, whereas 10% GO could stabilize up to 50% (v/v) water and provide gel-like properties by forming a bulk crystal network. By recrystallizing GO during homogenization, emulsions with smaller droplet sizes could be prepared. Moreover, the storage stability at 5 °C was better than at room temperature (20 °C). This research provides a novel way to fabricate Pickering W/O emulsions which have potential application in the food, pharmaceutics, and cosmetic area.

Keywords:
Pickering w/o emulsions, γ-oryzanol, crystals



Schematic diagram of γ-oryzanol stabilized Pickering water-in-oil emulsions

Acknowledgements:
The author acknowledges the financial support from the China Scholarship Council (No. 202206150019).

The structural, antioxidant and emulsifying properties of cellulose nanofiber-dihydromyricetin mixtures: Effects of composite ratio

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In this work, the effect of the cellulose nanofiber/dihydromyricetin (CNF/DMY) ratio on the structural, antioxidant and emulsifying properties of the CNF/DMY mixtures were investigated. CNF integrated with DMY via hydrogen bonding and the antioxidant capacity of mixtures increased with decreasing CNF/DMY ratio (k). The oxidative stability of emulsions was enhanced as the DMY content increased. Emulsions formed at a volume fraction (Φ) of 0.5 displayed larger size (about 25 μm), better viscoelasticity and centrifugal stability than those at a volume fraction (Φ) of 0.3 (about 23 μm). The emulsions at k = 17:3 and Φ = 0.5 exhibited the most excellent viscoelasticity. In conclusion, the DMY content in mixtures and the oil phase volume fraction exhibited distinct synergistic effects on the formation and characteristics of emulsions, and the emulsions could demonstrate superior oxidative and storage stability. These findings could provide a novel strategy to extend the shelf life of cellulose-based emulsions and related products.

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Acknowledgements:

The author gratefully acknowledges the financial support from the China Scholarship Council (CSC).

Modulating protein glycation in skim milk powder via low- humidity dry heating to improve its heat stabilizing properties

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The limited heat stability of skim milk powder (SMP) constrains its application in high-temperature processes. While dry heating can improve its thermal resistance, it often accelerates the advanced Maillard reaction, compromising protein quality. This study applied low relative humidity conditions (< 10% RH) during dry heating to modulate the Maillard reaction, aiming to enhance the heat resistance of SMP and derived recombined filled evaporated milk emulsions with less undesirable changes in color and solubility. SMP was subjected to dry heating at 80, 100, and 120 °C for durations ranging from 2 to 20 minutes (at 120 °C) and up to 16 hours (at 80 °C). The progression of the Maillard reaction and associated protein modifications were evaluated. The results indicated that the advanced Maillard reaction was retarded, evidenced by minimal color development and well-preserved protein solubility (90–97%, n=3), determined using the Lowry assay on the supernatants. The hydroxymethylfurfural and protein carbonyl contents increased only moderately with temperature and time. Moreover, the sulfhydryl group content remained largely stable, consistent with limited disulfide mediated aggregation. Heat treatment of SMP at 120°C for 10 min greatly improved its heat stability, as reflected by a 25-fold reduction in the volume-weighted average diameter ($D_{4,3}$; 95% CI = 3 to 47) and a 108-fold reduction in the consistency coefficient (K ; 95% CI = 12 to 200) of the SMP-derived sterilised recombined filled evaporated milk (RFEM) compared to the control. These findings demonstrate that dry heating under low RH helps to improve the functional properties of SMP without inducing the detrimental effects associated with advanced Maillard products.

Keywords:
Skim milk powder; Maillard reaction; Low humidity; High temperature; Recombined filled evaporated milk emulsion; Heat stability

Rheological properties of okra proteins

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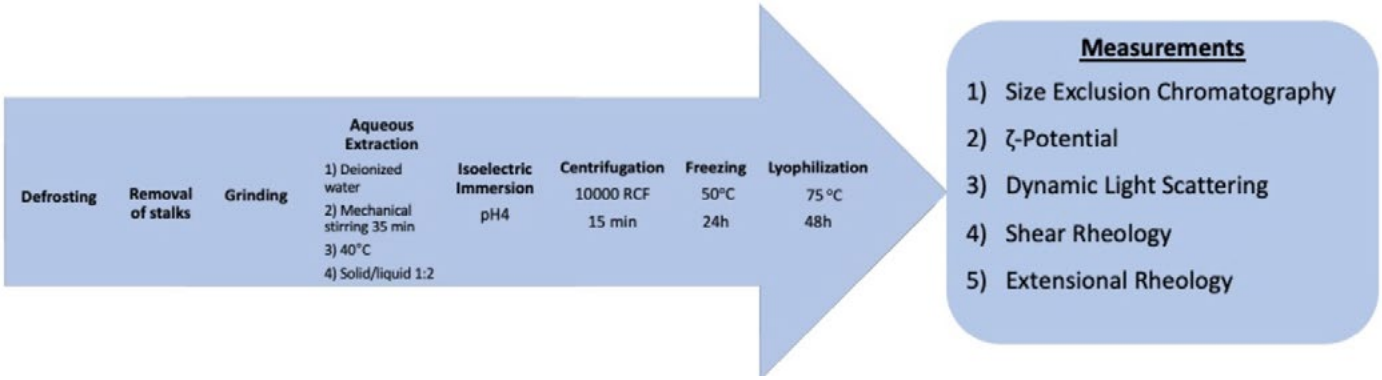
Okra (*Abelmoschus esculentus*) proteins are emerging plant-based macromolecules with notable functional potential, yet their rheological properties remain insufficiently explored. In this study, protein fractions were isolated through aqueous extraction and isoelectric precipitation at pH 4, and subsequently characterized in terms of their molecular and colloidal properties. Size exclusion chromatography revealed three distinct macromolecular populations, including aggregates or protein–carbohydrate complexes, as well as smaller peptides below 2 kDa. ζ-Potential and DLS measurements showed a clear pH-dependent behavior, with increased solubility at pH 5 and pH 7 due to enhanced electrostatic stabilization.
The rheological behavior of diluted protein solutions was investigated at different concentrations using shear and extensional rheology. Viscosity measurements demonstrated pronounced pseudoplastic, shear-thinning behavior, accurately described by the Herschel Bulkley model. At 50 s^{-1}, viscosity values remained below 100 mPa·s. Extensional rheology showed a strong concentration dependence, with filament breakup times increasing from 0.65 s at 3% to 1.08 s at 4%, accompanied by a sharp rise in relaxation time up to 4%. Further increases in concentration reduced filament-forming capacity due to system thickening.
Overall, the observed structure–rheology relationships highlight the potential of okra proteins as plant-based structuring agents.

Keywords:
Okra protein, viscosity



Protein extraction from okra and physicochemical characterization

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The influence of lactation period and gestation length on the colloidal structure of human milk

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Human milk (HM) is a natural oil-in-water emulsion, consisting of lipids, proteins, carbohydrates, minerals, and bioactive components. Its colloidal organization plays a significant role in nutrient delivery, digestion, and bioavailability for the developing infant. The (bio)chemical composition of HM can vary significantly throughout the lactation period, and differs between milk produced after full-term and preterm delivery.
This study investigates the influence of lactation stage and gestational age on the colloidal structure of HM. Milk samples were collected at two lactation stages (days): colostrum (1-7 days) and mature milk (30-60 days) with each participating donor providing a pair of samples. Samples were obtained from mothers of full-term and preterm infants, resulting in four experimental groups of milk samples. The colloidal structure of HM was characterized by particle size measurements using laser diffraction. Mid-infrared spectroscopy (MIRIS) was applied to determine the macronutrient composition of each sample. Statistical analyses were then conducted to evaluate whether variations in particle size distribution were systematically associated with lactation stage, gestational age, and milk composition.
Our findings indicate differences in the colloidal properties of HM between different groups analysed. Variations in particle size distribution were detected, suggesting structural changes that may occur during lactation. Associations between compositional parameters and particle size were also observed, pointing to a potential relationship between milk composition and colloidal organization. These insights may contribute to the development of infant formulas that better mimic the structural and compositional characteristics of human milk at different stages of lactation and dedicated to either full-term or preterm infants.

Keywords:
human milk, colloidal structure, particle size measurements, mid-infrared spectroscopy, statistical analysis

Acknowledgements:
The project was financed by the National Science Centre, Poland (grant no. 2022/47/I/NZ9/02749).

Aqueous dairy protein behaviour in plant protein-stabilized oil-in-water emulsions

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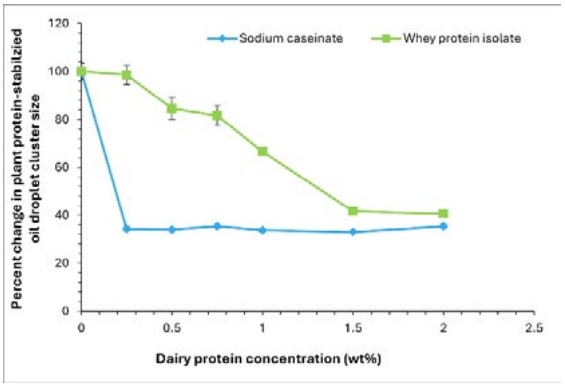
The stability and flowability of protein-stabilized oil-in-water (O/W) emulsions depend largely on the protein's surface activity and concentration, as insufficient or excessive protein can cause bridging or depletion flocculation, respectively [1]. Often, to improve emulsion stability and to increase the protein load of an emulsion-based food, it is necessary to add excess protein to the emulsion than what is required for simple emulsification. Dairy proteins are highly desirable for this purpose due to their higher nutritional quality and solubility. However, as plant proteins are in high demand due to their environmental sustainability, the aim of the present work was to develop hybrid systems and to understand how the complex interactions between plant-protein-stabilized droplets and excess soluble dairy proteins in the continuous phase influence the stability and rheology of the emulsions. As the size and shape of excess biopolymer can strongly affect inter-droplet interactions [2], the effect of flexible, random-coiled sodium caseinate (SC) was also compared with globular whey protein isolate (WPI).

Stock solution of either SC or WPI was added to faba bean protein isolate (FPI)-stabilized 30 wt% O/W emulsion to generate hybrid systems with 20% oil, 2% FPI and 0 to 2% dairy protein. All emulsions showed extensive droplet aggregation. Over 4 weeks, a sustained reduction in cluster size was observed in the presence of dairy protein, with SC being more effective at controlling cluster growth. Viscoelastic analysis revealed that controlled droplet clustering reduced gel strength of the emulsions in the presence of both SC and WPI. All emulsions remained mostly fluid, exhibiting weak gel-like behaviour even at 2 wt% dairy proteins. The viscosity of all emulsions with various amounts of dairy proteins did not differ significantly, indicating that a higher concentration of soluble protein in the emulsion continuous phase could be incorporated without affecting their flowability.

SDS-PAGE of interfacial proteins recovered from the emulsion showed that both SC and WPI were able to partially replace plant proteins from the oil droplet surface, which was also confirmed by interfacial adsorption dynamics. While the extent of depletion flocculation could be influenced by dairy proteins interacting with the droplets, the size ratio between the droplet clusters and the dairy proteins could substantially affect the range of attractive interactions, thereby influencing cluster size [3]. Electrostatic charge may also accumulate as the clusters grow, eventually limiting their growth [3]. In conclusion, the aggregation behaviour of plant protein-based emulsions was reduced by adding excess dairy proteins, thereby creating a flowable emulsion with suspended clusters.



Change in droplet cluster size with the addition of increasing concentration of sodium caseinate or whey protein isolate.

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Structuring of High-Oleic Sunflower Oil with Ethylcellulose as a Saturated Fat Alternative

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The food industry widely uses palm oil (saturated fatty acid content ~50%) in formulations such as biscuits and chocolates because it provides desirable physical and functional characteristics. Oleogels can serve as alternatives to palm oil. Nevertheless, structuring oleogels remains challenging because their physical properties depend on multiple parameters, including the type of oil, the structuring method, viscosity, and gelling agent concentration. This study aimed to determine the physical characteristics (oil-binding capacity, texture, thermal properties, and color) of oleogels produced using different structuring techniques (direct heating, Ultra-Turrax homogenization, and ball milling) and to compare them with a palm-based fat (shortening).
Ethylcellulose with different viscosities (EC20, EC45, EC100) and concentrations (8-18%) was used for structuring. For direct heating, the ethylcellulose-oil mixture was heated to 178 °C on a thermoregulated plate heater. Ultra-Turrax homogenization was performed at 15000 rpm for 3 min at 155 °C. Ball-milling was performed on ethylcellulose at 30 Hz for 10 min. After Ultra-Turrax and ball-milling, the mixtures were heated to 178 °C by direct heating. The molten mixtures were transferred into glass containers and allowed to cool at 25 °C for 1 h. Subsequently, the oleogels were stored at 4 °C until analysis.
Increasing the EC20 concentration in the oil increased the oleogels' oil-binding capacity. Ultra-Turrax homogenization increased the oil-binding capacity, whereas ball milling weakened it. A similar trend was observed for oleogels prepared with EC45 and EC100; however, this effect was not evident at the highest concentrations, as the oil-binding capacity reached a maximum. The effects of Ultra-Turrax homogenization and ball milling on polymer–oil interactions were further confirmed by hardness measurements, which indicated enhanced interactions after Ultra-Turrax treatment and generally weakened interactions after ball milling. The glass transition temperatures of EC20, EC45, and EC100 were 142, 147, and 145 °C, respectively, while their melting temperatures were 183, 188, and 190 °C; no differences related to the preparation method were observed. Color values did not vary with concentration or pretreatment. Oil-binding capacity and hardness values depended on the ethylcellulose concentration, oil type, and structuring method. The lowest ethylcellulose concentrations that showed no significant differences ($p > 0.05$) compared with shortening for these properties were 15% EC20 prepared by Ultra-Turrax homogenization and 13% EC45 prepared by direct heating. High oleic sunflower oil structured by ethylcellulose can be an alternative to palm oil-based saturated fat, and different methods can be used to structure oleogels.

Keywords:
Oleogel, ethylcellulose, high-oleic sunflower oil, ball milling, Ultra-Turrax

Acknowledgements:
This study is funded by the Hacettepe University Scientific Research Projects Coordination Unit (Project Code: FOA-2024-21153)

Evaluation of Ethylcellulose-Based Oleogels from High-Oleic Sunflower Oil in Biscuit Production: Effects on Texture, Colour, and Spread Ratio

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Saturated fats are utilised in the baking industry for their techno-functional properties. However, the adverse health effects associated with high consumption of saturated fat are well recognised. Therefore, converting high-oleic sunflower oil into a saturated-fat substitute using ethylcellulose was aimed at use in biscuits as a promising strategy.
In this study, 18 oleogels were produced using ethylcellulose of various viscosities (20, 45, and 100 cp) and concentrations (8-18%) via hot-plate and ultraturrax-combined hot-plate methods. The performance of these oleogels in biscuits was assessed using two biscuit production procedures: creaming and all-in-one. Cookies were made using shortening as the control and neat high-oleic sunflower oil as the non-structured reference. In the creaming method, fat and sugar were mixed first, followed by the addition of an aqueous mixture containing water-soluble ingredients to form a cream. Flour was added last and mixed briefly to form the dough. In the all-in-one method, all biscuit formulation ingredients were mixed simultaneously during dough preparation. Biscuit doughs were shaped to the same thickness and diameter, then baked at 180 °C for 4.5 minutes. The spread ratio (diameter/height), colour (L*, a*, b*), and texture profile analyses (hardness and fracturability) of the biscuits were conducted.
Biscuits containing oleogel produced by the creaming method had significantly greater hardness than biscuits containing shortening, regardless of the oleogel production method ($p<0.05$). This increased hardness can be attributed to the oleogel's ability to prevent sugar from reaching water, which is then absorbed by the flour, promoting gluten formation. Biscuits containing oleogels produced by the all-in-one method with 12% ethylcellulose (20 cp) had the greatest hardness similarity to those made with shortening. Additionally, the colour and spread ratio of these biscuits were comparable to those of biscuits containing shortening. It was concluded that, using this method, high-oleic sunflower oil alone caused the biscuits to rise rather than spread, a problem mitigated by the oleogel. Overall, oleogel made with ethylcellulose from high-oleic sunflower oil is suitable for biscuit production using the all-in-one method and provides a healthy alternative to saturated fat–based shortenings.

Keywords:
Oleogel, ethylcellulose, high-oleic sunflower oil, biscuit

Acknowledgements:
This study is funded by the Hacettepe University Scientific Research Projects Coordination Unit (Project Code: FOA-2024-21153)

Beyond Interfacial Tension: Elastic Effects in Turbulent Emulsion Formation in Rotor-Stator Mixers

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Many food emulsions are produced in turbulent emulsification devices. Emulsifiers are almost always present in food, naturally or added, and are well-known to lower the interfacial tension between the phases. The lowering of the interfacial tension affects the process of coalescence but also the initial drop breakup during emulsification. However, other mechanisms have been suggested. Under some conditions, some emulsifier can make the drops more difficult to break, possibly due to emulsifiers imposing an interfacial elasticity. This has been described as an increase in effective viscosity [1] or interfacial tension [2]. These elastic effects have also been observed in turbulent emulsifications devices, i.e., in a model of a homogeniser [3]. To investigate what effect emulsifiers have on drop breakup, beyond lowering interfacial tension, different emulsifiers were screened using emulsification experiments with Medium-Chain Triglycerides (MCT) oil in water, a rotor stator mixer, and different concentrations of the emulsifier. Coalescence during emulsification was avoided by using a low volume fraction of dispersed phase. Results show that the effect of emulsifiers on drop breakup cannot be explained solely by the lowering of the interfacial tension. An elastic effect appears to give rise to an extra stabilisation at intermediate concentrations in some conditions. The effect depends on the molecular properties of the emulsifier.

Keywords:
Turbulent emulsification, interfacial elasticity effects, rotor-stator mixer, emulsifiers, drop break-up, interfacial tension.

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Acknowledgements:
Financial support from the Swedish Research council (VR 2024-04823) is gratefully acknowledged.

Impact of pH and κ-carrageenan addition on mixing behaviour and heat-induced gelation of potato protein isolate

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In recent years, plant-based meat analogues have attracted increasing attention due to environmental pressures, animal welfare considerations and emerging public health concerns related to meat products. However, heat-induced gels structured by plant proteins alone often exhibit limited network connectivity and poor resilience, constraining texture and physical stability. Therefore, polysaccharides are commonly incorporated because they can improve structure and physical stability in a condition-dependent manner. In aqueous media, protein–polysaccharide mixtures can exhibit distinct mixing behaviours, including relatively homogeneous co-dispersed mixtures, associative complexation, or segregative phase separation arising from thermodynamic incompatibility. Among condition variables, pH is particularly influential because it regulates protein net charge, electrostatic interactions, and hydration, thereby shifting the balance among these mixing states. However, systematic investigation of the impact of mixing behaviour on subsequent heat-induced gelation remains limited. To address this gap, this study focuses on potato protein isolate (PPI)–κ-carrageenan (KC) systems at a fixed salt level (1.5 wt.% NaCl) and examines the impact of pH and KC concentration on the PPI–KC mixing behaviour, studied through turbidity and protein solubility, and on heat-induced gel structure, as assessed by rheological measurements and water-release-based stability indices.

The results showed that pre-heating mixing behaviour of the PPI–KC system was highly sensitive to pH and KC concentration: at pH 7, turbidity slightly increased with increasing KC while protein solubility remained high, whereas at pH 3, increasing KC more readily reduced protein solubility, consistent with stronger aggregation. Heat-induced gelation responses were likewise condition-dependent. Final gel strength (G′) and critical strain (γ_c) varied significantly with pH and KC: G′ was lower at pH 3 and further decreased as KC increased, whereas γ_c was generally higher at elevated pH and was higher at 0.5 wt.% KC than at 1.0 wt.% KC. Water-release-based stability indices exhibited patterns consistent with G′. Overall, these results indicate that pH is the dominant factor under 1.5 wt.% NaCl, whereas the effect of KC is strongly condition-dependent. Compared with pH 5/7, at pH 3 systems were more prone to aggregation, formed weaker gels, and exhibited greater water release, and increasing KC did not confer consistent gains in gel structure or stability.

Keywords:
Potato protein isolate, κ-carrageenan, pH, Mixing behaviour, Heat-induced gelation

Acknowledgements:
This work was funded by China Scholarship Council and Internal Funds KU Leuven.

Plant protein-food gum complex-based foamed emulsions for application in cappuccino-style beverages

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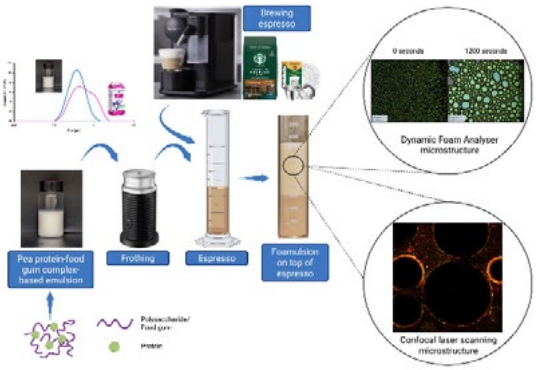
Cappuccino-style beverages such as cappuccino and latte are extremely popular worldwide. A key component in their preparation is dairy milk foam. Although plant-based substitutes from oats, coconut, and soy are commercially available, the foams produced from these barista-style beverages are below par compared to their dairy milk counterparts [1]. In addition, the use of pulse proteins, such as pea proteins, in the coffee industry is limited due to challenges in simultaneously delivering both emulsification and foaming behaviour, and their tendency to undergo isoelectric aggregation at coffee pH [2].Therefore, current research focuses on the utilization of a pea protein-food gum complex to develop stable oil-in-water emulsions [3] that will form highly stable foamed emulsions (foamulsions), even when added to a brewed espresso. Various concentrations of pea protein and food gum have been used to prepare canola oil-in-water emulsions with a high-pressure homogenizer. The emulsions were subsequently foamed using a commercial frother to develop foamulsions, followed by, assessment of their foaming behaviour independently and when added on top of freshly brewed espresso. Rheology and microstructure of the foamulsions were also characterized.

All prepared emulsions exhibited a monomodal size distribution, with an average droplet size of 0.4-0.5 μm, compared to 0.67 μm for dairy milk. Storage stability over 4 weeks, as well as accelerated gravitational separation analysis, revealed that emulsion stability improved with biopolymer concentration up to a critical threshold. Foamability of the resulting foamulsions increased with total biopolymer concentration. On top of espresso, the foamulsions exhibited optimum foam stability and whitening power similar to dairy milk. The Dynamic Foam Analyzer-based microstructure showed the lowest bubble count and highest bubble radius for dairy milk foam compared to foamulsions. Confocal laser scanning microscopy further showed that both proteins and oil droplets were present at the air-emulsion interface, suggesting a synergistic contribution to enhanced foam stability.

Based on overall emulsion stability and optimum foaming characteristics, the best-performing emulsion was further evaluated by mixing with varying sugar concentrations (0-3% w/w) and by adding the foamulsions on top of espresso made with varying water hardness levels (0-400 ppm). The viscosity of the emulsion, as well as the foamulsion, increased with the addition of sugar. The foamulsion stability on top of espresso was not significantly affected by sugar or water hardness, indicating high stability of foamulsions under diverse environmental conditions. Overall, the pea protein-food gum complex demonstrated strong potential as a functional, plant-based ingredient for developing stable plant-based foamed emulsions for cappuccino-style beverages.



Foamed emulsion developed from plant protein-food gum complex-based emulsion, poured on top of freshly brewed espresso, along with microstructure images of the foamulsion using dynamic foam analyser and confocal laser scanning microscopy

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Comparative study of faba and lupin proteins as sustainable emulsifiers: interfacial behaviour and physicochemical stability in the presence of healthy oils.

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The food industry is currently undergoing a paradigm shift toward plan-based formulations for replacing that derived from animals to mitigate the environmental footprint associated with intensive livestock farming. This approach addresses at the same time the growing consumer demand for "clean-label" and health promoting food products to prevent disease and improve physical and mental health (Bai et al., 2021; Medina-Remón et al., 2018). In this sense, legume proteins, particularly from lupin and faba, are known by their remarkable interfacial activity and ability to stabilize complex food colloids, such as oil/water (O/W) emulsions. Thus, research on the techno-functional behaviour of these legumes is crucial for the strategic development of plant-based food matrices that align with the actual nutritional trends. Moreover, the employment of health-promoting specialty oils, rich in unsaturated fatty acids, help to prevent a wide range of health problems, including cardiovascular disease, inflammation, diabetes (Gumus et al., 2017).
This work provides a comprehensive comparison between faba protein concentrate (FPC) and lupin protein concentrate (LPC) as emulsifiers in O/W emulsions, formulated with different healthy oils (chia, nut and sesame), using different oil to water ratio (10:90 and 40:60 % (w/w)). The emulsifying properties of these proteins were evaluated encompassing the analysis of interfacial properties (protein adsorption kinetics and both dilatational and shear interfacial rheology) and emulsifying properties, characterised by droplet size distribution.
The results obtained from the present work help to select the type and nature of oil, as well as the protein concentrate (FPC or LPC) to produce stable emulsions containing health promoting food ingredients.

Keywords:
plant-based proteins, specialty oil, Dilatational, Shear, Interfacial, Emulsions

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Acknowledgements:
This research has been funded by FEDER / Ministerio de Ciencia e Innovación - Agencia Estatal de Investigación through the MCIN/AEI/10.13039/501100011033 / FEDER, UE, through the project PID2022-142663OB-I00 project.

Modification of the rheological properties of edible hydrocolloid macrogels by novel classes of filler particles: microgels and nanobubbles

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Many hydrocolloids such as starch and gelatin are used in various food products as gelling agents for creating network structure in the matrix. To design the desired food texture, hydrocolloids are occasionally modified with chemical treatments and/or used in combination with other hydrocolloids. Another approach for improving physical properties of gels is the addition of filler particles. A series of studies has investigated the ability of edible filler particles, most typically emulsified oil droplets, to regulate physical properties of gels. Here, we focus on novel classes of particles, i.e., microgels and nanobubbles, which have recently attracted great attention in the field of colloid science. The aim of this work is to clarify the effect of microgels and nanobubbles on the rheological properties of hydrocolloid-based macrogels.

For the preparation of microgels, a heated agar solution was step-wisely cooled with constant agitation to prepare a coarse microgel dispersion, which was further homogenized with a high-speed blender to obtain a fine microgel dispersion. For the generation of nanobubbles, we used a commercial nanobubble generator connected with nitrogen gas to obtain a nanobubble dispersion. The microgel and nanobubble dispersions were subjected to particle size measurements based on laser diffraction or dynamic light scattering. Macrogels were prepared using several hydrocolloids, e.g., starch, gelatin, deacetylated gellan gum, as the matrix. These hydrocolloids were solubilized or dispersed in the microgel or nanobubble dispersion, followed by gelation under appropriate conditions. The rheological properties of the obtained macrogels were analyzed by a compression test by a texture analyzer. The microscopic observations were conducted by using a scanning electron microscope.

The particle size analysis of these filler particles shows that the volume-weighted mean size of the agar coarse and fine microgels was approximately 250 and 50 μm, respectively, while that of the nanobubbles was approximately 200 nm. The agar microgels behaved as an active or negative filler depending on the hydrocolloid used for the matrix, probably due to differences in the interactions between the filler and matrix. On the other hand, although the submicron nanobubble hardly affected the strain-stress curve of the starch macrogels just after preparation, the time-dependent hardening of the nanobubble-incorporated starch gels during the storage was relatively suppressed compared with that of the control sample without nanobubble incorporation. Our findings imply that microgels and nanobubbles can be potentially applicable for controlling rheological properties and physical stability of products based on hydrocolloid gels.

Keywords:
Macrogel, filler particle, microgel, nanobubble

Acknowledgements:
This work was supported by JSPS Grants-in-Aid for Scientific Research Grant Numbers JP20K13797 and JP24K17848.

Effect of Hydration Liquids on the Dehydration Dynamics of Hydrogel

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Understanding the dehydration behaviour of hydrogel beads is vital for their effective use in sectors such as food technology, agriculture, and biomedical applications. This study investigates the impact of hydrating liquid composition on the evaporation dynamics of polyacrylic hydrogel beads. The beads were hydrated in a range of solutions, including saline, sugar water, egg white, and blood, and benchmarked against hydration in pure distilled water.
Among all tested media, beads hydrated in distilled water achieved the highest swollen volume, reflecting superior water absorption. The evaporation response was closely linked to the nature and concentration of solutes in the hydrating liquid, which modulate the hydrogel network's ability to retain water. The final dry diameter of the beads was further shaped by solute diffusion and internal crystallization processes. Notably, sugar water hydration resulted in the highest final-to-initial mass ratio, suggesting a unique role for sugar in enhancing water retention and slowing evaporation.

Keywords:
Hydrogel, dehydration, hygroscopic, capillary bridge, blood.

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Acknowledgements:
We thank Giovanna Mottola Ghigo and Marie Rose Muccio for collecting the blood and Claude willy Banry Mathew for his assistance in experiments and analysis. The authors acknowledge the ANR – FRANCE (French National Research Agency) for its financial support of the BlooDrop project n°ANR-23-CE-0013.

Optimization of Culinary Application of Aquafaba in Food foams

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Aquafaba, the cooking water of legumes, has become popular as a vegan egg substitute [1]. However, its application in haute cuisine faces challenges related to standardization, stability, and, critically, the integration of flavor without compromising food structure, for example in food foams [2]. This study had a dual objective: first, to optimize the foaming properties of aquafaba, and second, to develop a novel culinary technique for creating stable, intensely flavored foams.

For optimization, chickpea aquafaba (chickpea:water ratio 1:3) was prepared, and its foaming capacity (FC) and foam stability (FS) were analyzed at five pHs (3.5, 4.0, 4.5, 5.0, and 5.5). The results identified pH 4.5 as the optimal condition, achieving the best balance between maximum foaming capacity (FC 1324%) and maximum foam stability (FS 99.1% after 60 min).

For gastronomic applications, a "reduction and replacement" technique was developed, in which aquafaba was volumetrically reduced (~50%) to concentrate its proteins and subsequently reconstituted with a flavoring liquid. This approach overcame the dilution problem, producing robust foams (FC 958%, FS 98.6%) with intense flavor. The effectiveness of the optimized aquafaba was validated through its use in emulsions, baked doughs, and mousses.

This work provides a specific quantitative value (pH 4.5) for aquafaba standardization and introduces a replicable technique that enables its use as a high-performance ingredient in creative cuisine, effectively addressing the challenge of flavor integration.

Keywords:
Aquafaba, legume proteins, stable foam, flavor integration

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APPLICATION OF LASER DIFFRACTION TO CHARACTERIZE THE DROPLET SIZE DISTRIBUTION (DSD) OF NATURAL WATER-IN-OIL (W/O) EMULSIONS PRESENT IN FRESH UNFILTERED VIRGIN OLIVE OILS.

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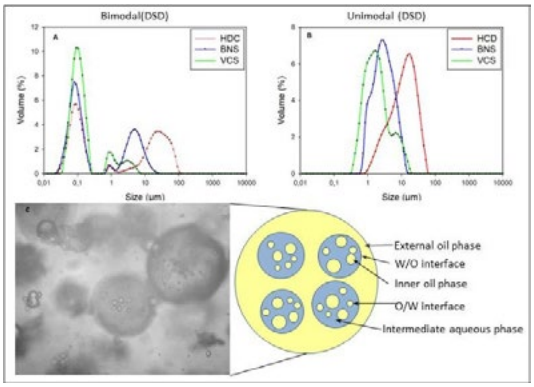
In this work, laser diffraction is applied for the first time to analyze the droplet size distribution of natural water-in-oil (w/o) emulsions present in unfiltered virgin olive oils from the horizontal decanter centrifuge, vertical centrifuge separator and bottle natural settling. In this first approach, two different droplet size distributions were observed with unimodal and bimodal distributions in the unfiltered virgin olive oils analyzed. Droplet size distributions also showed that unfiltered virgin olive oils from horizontal decanter centrifuge presented larger water droplets than those clarified by vertical centrifuge separator and bottle natural settling. A lower droplet size can indicate a higher emulsions stability present in the unfiltered virgin olive oils clarified by vertical centrifuge separator. In parallel, epi-fluorescent microscopy revealed that horizontal decanter centrifuge oils contain a complex colloid system, including oil-in-water-in-oil (O/W/O) double emulsions. Accordingly, laser diffraction appears as a useful methodology to characterize the natural emulsions present in the unfiltered virgin olive oils and understand how the emulsion is generated during oil extraction process and regulate the process variables.

Keywords:
Unfiltered virgin olive oils, emulsion, laser diffraction, droplet size distribution, moisture, turbidity, microscopy



Droplet size distribution of unfiltered virgin olive oils (A - UVOO1 and B - UVOO2) from horizontal centrifuge decanter, bottle natural settling and vertical centrifuge separator. C - Epi-fluorescent microscopy image (50x) of oil-in-water-in-oil (O/W/O) emulsions present in the UVOO.

Acknowledgements:
This work was supported by the projects: PR.AVA23.INV2023.023 and PR.TRA23.TRA2023.001, co-financed in 80% by the 'Programa Operativo FEDER' into the 'Programa Operativo de Andalucía' 2021-2027. "M.A.F.R., T.dC.S. and J.M.V. acknowledge funding from projects PID2023-149387OB-I00, and 275 PID2023-147135OB-I00 funded by MICIU/AEI/10.13039/501100011033 and by FEDER, EU. Also an EMERGIA grant with reference EMC21_00008 and grants C-ING-208-UGR23 and C-EXP-187-UGR23 funded by Consejería de Universidad,Investigación e Innovación de la Junta de Andalucía, and ERDF Andalucía 2021-2027".

Engineering Porosity: Challenges and Solutions in Freeze-Drying Colloidal Suspensions

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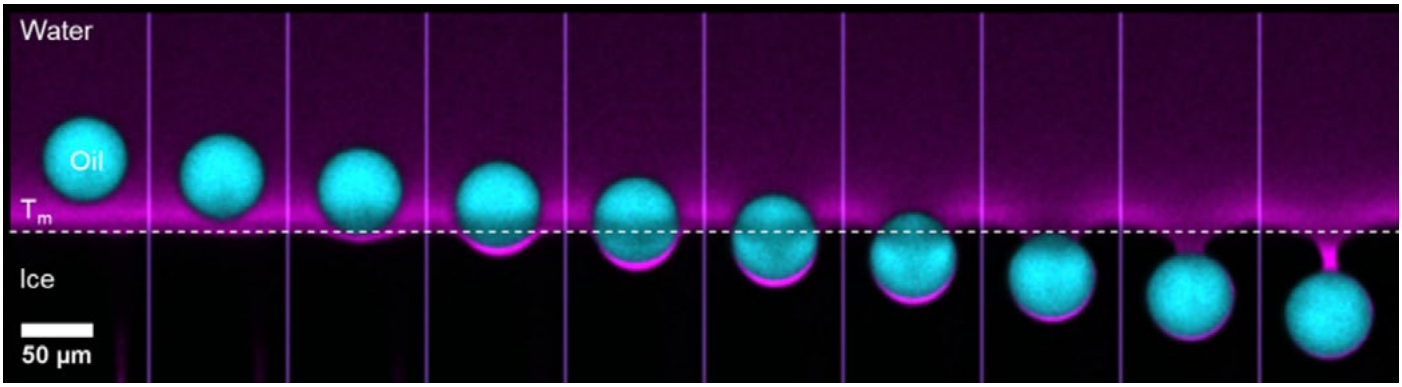
Freeze templating is a technique that utilizes controlled freezing of colloidal and emulsion systems to create porous structures in food products, particularly during the freeze-drying process for beverages like coffee. This approach effectively preserves flavor and aroma while enhancing convenience, resulting in high-quality instant coffee that meets consumer expectations.
In this presentation, we will explore how freeze templating can be employed to develop unique porous architectures within food matrices. By fine-tuning the freezing process of emulsions and foams, it is possible to enhance porosity, which is critical for improving rehydration properties and reducing drying times [1]. The successful reconstitution of dehydrated beverages is essential for retail and dispensing systems, where consumers seek quick and seamless preparation. Consequently, optimizing powder formulation, viscosity, and processing is crucial to achieving these objectives [2]. Additionally, variations in porosity impact the density and stability of freeze-dried products, influencing their overall quality.
Recent advancements in in-situ imaging techniques have yielded valuable insights into the freezing behaviors of soft materials, including droplets and bubbles [3]. Analyzing these behaviors enhances our understanding of how surface interactions and solute effects shape microstructure and porosity. This knowledge is vital for improving rehydration performance, ensuring that freeze-dried beverages consistently deliver the desired flavor and quality. Furthermore, we will address the current challenges faced by the food industry regarding the freeze-drying of colloidal suspensions.

Keywords:
emulsions, foams, freezing, drying, porosity



Interaction of a droplet with a moving ice-water interface. Ice is in black, oil in cyan and water in magenta [3]

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Effect of fat source on the microstructure and rheology of plant-based protein emulsions for meat analogue applications

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Due to environmental and health concerns, demand for meat alternatives is rising, increasing the interest in plant proteins and meat analogues. Fat plays an important role influencing texture and mouthfeel in meat analogues. This study investigates the effect of different fat sources on the microstructure, rheology and juiciness of oil-in-water emulsions used in plant-based patties. Emulsions were prepared using soy protein with rapeseed oil, beef tallow, palm oil, and palm olein and were characterised using Coherent Anti-Stokes Raman Scattering (CARS) microscopy and rheology. These emulsions were then incorporated into soy-based patties, which were analysed uncooked by CARS microscopy.
Microstructural analysis showed that rapeseed oil emulsions had significantly smaller and round fat particles, whereas other fat sources formed larger, irregularly shaped, and agglomerated fat microparticles. Lipidic area analysis indicated that rapeseed oil and palm olein emulsions had the highest fat area, while beef tallow and palm oil exhibited lower values. Rheological results showed that all emulsions exhibited predominantly elastic (solid-like) behavior. Beef tallow emulsions demonstrated the highest gel strength but were more sensitive to temperature increases, while palm olein emulsions showed higher resistance to deformations.
After incorporation into patties, microstructural analysis revealed that mixing altered fat particle morphology, leading to irregular and agglomerated fat structures across all formulations. Despite retaining a high number of fat microparticles, patties with rapeseed oil emulsions exhibited morphology similar to the patties prepared with other fat emulsions.
These findings highlight the impact of fat source on emulsion characteristics and their role in optimizing plant-based meat formulations.

Keywords:
plant-based proteins, emulsions, microstructure, rheology, meat analogues

Influence of water content on the structural properties of insect oil–based oleogel emulsions

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Insect-derived oils represent promising and sustainable lipid sources for structured fat systems; however, their performance in oleogel-based emulsions is strongly influenced by formulation parameters, particularly water content. Water significantly influences the textural and rheological properties as well as the physical stability of these emulsions by affecting network formation and phase interactions [1,2]. This study investigated the effect of water content on the structural and functional properties of insect oil–based oleogel emulsions. The oleogel was prepared using insect oil and 3% sunflower wax as oleogelator. Water-in-oleogel emulsions were subsequently formulated by incorporating ultrapure water at varying proportions into the preformed oleogel (oleogel-to-water ratios, w/w: 100:0, 95:5, 90:10, 85:15, 80:20, and 75:25), with 2% soybean lecithin as emulsifier. The effects of water content on the structural properties—including rheological, textural, thermal characteristics, and oil retention—were evaluated over a 30-day storage period at 20 ± 5 °C. Water content exerted a pronounced influence on the structural properties of the oleogel emulsions, leading to significant alterations in their rheological behaviour, whereas their thermal properties remained largely unchanged. Textural properties were similarly affected: hardness decreased as water content increased up to a 90:10 (oleogel:water) ratio. Beyond this point, the trend reversed, with hardness increasing in the 85:15 and 80:20 formulations; notably, the 85:15 emulsion exhibited higher hardness than the 95:5 and 90:10 systems. Oil retention decreased with water addition up to 15%; however, at higher water levels (80:20 and 75:25), oil retention improved, likely due to increased entrapment of water within the lipid network, which enhanced the structural integrity of the emulsions. Overall, the study demonstrates that water content plays a critical role in determining the structural and functional properties of insect oil–based oleogel emulsions, enabling modulation of gel strength and oil retention. These findings offer a foundation for the development of sustainable, health-oriented, and tailored fat-mimicking systems.

Keywords:
Rheological properties, textural parameters, Oil retention, Stability, Emulgel, Thermal properties

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Acknowledgements:

This study was supported by the Portuguese Foundation for Science and Technology (FCT) under the scope of the strategic funding of UIDB/04469/2020 unit, the project ESSEntial (DOI: 10.54499/PTDC/BII-BTI/1858/2021), and by LABBELS – Associate Laboratory in Biotechnology, Bioengineering and Microelectromechanical Systems, LA/P/0029/2020. Authors also acknowledge the project VIIAFOOD for its Assistant Research program under the scope of "Agenda para a Inovação Empresarial – VIIAFOOOD – Plataforma de Valorização, Industrialização e Inovação comercial para o Agro-alimentar" (Project n.° 37, application n.° C644929456-00000040) funded by the Plan for Recovery and Resilience (PRR) and by the European Funds Next Generation EU.

BSA aerogel-based affinity columns for the analysis of ochratoxin A

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Ochratoxin A (OTA), a highly toxic mycotoxin produced by fungi of the *Aspergillus* and *Penicillium* genera, is widely distributed in numerous food commodities. Due to its public health relevance and low regulated limits, sensitive analytical methods are required to monitor OTA occurrence [1]. To achieve this, different matrix clean-up approaches are frequently used to remove interferents or to concentrate the toxin. In this context, bovine serum albumin (BSA), which possesses strong affinity for OTA, emerges as an alternative for toxin capture [2]. Protein-based aerogels are highly porous three-dimensional networks, obtained from protein gels, which exhibit high structural stability, large specific surface area, high porosity, low density, and enhanced accessibility to binding sites [3]. Therefore, BSA-based aerogels represent a promising platform for the development of novel solid-phase extraction (SPE) approaches for OTA determination in food matrices. Aerogels were prepared using heat-induced gelation followed by lyophilization.
Preparation conditions were optimized using a Box–Behnken experimental design. The evaluated production variables were protein concentration (5-10 % w/v), temperature (70-90 °C), and ionic strength (absence or presence of PBS). Aerogel characterization included texture profile analysis (TPA), porosity, water retention capacity, and volume variation. Optimal production conditions were 8.75 %, 85 °C, and 0.75 for BSA concentration, temperature, and salt ratio, respectively. After micronization, the aerogel material was packed into 3 mL SPE columns, and the OTA capturing method was optimized and validated over a concentration range of 0.01-3 $\mu g \cdot L^{-1}$. Seven beers and eleven fruit juices were analysed using both BSA-SPE columns and commercial immunoaffinity columns (IAC) for comparison. OTA quantification was done by HPLC with fluorescence detection.
BSA-SPE showed OTA recoveries ranging from 94-103 % in beer and 92-108 % in fruit juices. Detected OTA levels ranged from 0.003 to 0.021 $\mu g \cdot L^{-1}$ (BSA-SPE) and from 0.001 to 0.017 $\mu g \cdot L^{-1}$ (IAC) in beer. In fruit juices, OTA levels ranged from 0.003 to 0.033 $\mu g \cdot L^{-1}$ (BSA-SPE) and from 0.007 to 0.056 $\mu g \cdot L^{-1}$ (IAC). Results with both methods showed good agreement, and demonstration that the proposed approach is a suitable alternative for OTA quantification.

Keywords:
Protein-based aerogels; Bovine serum albumin; Affinity solid-phase extraction; Ochratoxin A; Food matrix analysis

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Acknowledgements:

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Mesoscale Insights into Polysaccharide Microgel Stabilization of Food Emulsions via DPD Simulations

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The stability and functionality of food emulsions are primarily controlled by the organization of biopolymers at liquid–liquid interfaces[1]. Polysaccharide-based microgels have emerged as promising stabilizers due to their tunable softness and ability to form viscoelastic interfacial films, making them ideal for applications such as fat replacement and nutrient delivery[2]. While molecular dynamics (MD) simulations have successfully identified the specific molecular regions of soy hull polysaccharide (SHP) that drive interfacial anchoring, MD is limited by short timescales and small spatial scales[3]. To overcome these limitations, this study utilizes Dissipative Particle Dynamics (DPD) to investigate the adsorption, deformation, and long-term interfacial assembly of these microgels[4]. By capturing large-scale network formation and macroscopic viscoelastic properties that are computationally inaccessible to all-atom MD, DPD provides a predictive framework for tailoring polysaccharide microgels for specific food applications, bridging molecular-scale properties with macroscopic functional performance.

Keywords:
DPD simulation, microgel, polysaccharides

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Effectiveness of Sucrose Fatty Acid Esters in Beverage Applications: Foam Suppression in High Protein Beverages and Emulsion Stability in Almond Milk

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Plant-based milks are increasingly used as dairy alternatives and constitute complex, multi-component food systems with diverse botanical sources, lipid compositions, and stabilizer selections. In contrast, cow's milk has been extensively studied, and in Japan sucrose fatty acid esters (SE) are widely used to stabilize emulsions in milk-coffee beverages, reflecting their well-recognized interfacial functionality in the food industry. Although plant-based milks are known to present multiple formulation challenges—beyond emulsion stability, including foaming, sedimentation, and mouthfeel—systematic studies addressing these issues remain limited.

This study focused on almond milk as a model plant-based milk and examined the role of SE in physical stability under conditions relevant to beverage processing, including heat sterilization (121℃ 10 min.) when SE was used alone or in combination with thickeners. In addition, we investigated foaming issues in high-protein beverages by comparing soy- and whey-protein systems with different degrees of ingredient processing. To control foam, we evaluated how SE type (HLB value) influences defoaming performance across different protein systems.

In almond milk, SE with HLB of 16 (0.1%) suppressed creaming by visual observation, despite only a limited change in median droplet size (15 μm to 13 μm) compared to the control (no additive). The combination of SE with HLB of 16 (0.1%) and thickeners (gellan gum 0.02% and guar gum 0.02%) further reduced the median droplet size (8.5 μm to 5.1 μm) and enhanced creaming suppression, whereas thickeners alone showed no apparent suppression of creaming.

For protein beverages, 2%-protein samples prepared from soy milk, soy protein isolate, and whey protein isolate were evaluated. In soy milk, SE with HLB of 5–9 (0.1%) exhibited defoaming effects, while no clear defoaming effect was observed for soy protein isolate under the conditions tested. In whey protein isolate, SE with HLB of 3–7(0.1%) showed defoaming effects. Foaming properties differed depending on protein types and ingredient processing. It was suggested that SE may exhibit foam control by desorbing foaming components or through competitive adsorption.

These results indicate that SE can contribute to emulsion and foam control in actual beverage systems through appropriate HLB selection and formulation design, including combination with thickeners.

Keywords:
plant-based milk, almond, soy, whey, protein, sucrose fatty acid esters, emulsion, foaming, beverage

Surface adsorption of pea legumin upon tryptic hydrolysis: A combined theoretical and experimental study

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For expanding plant protein utilization, it is vital to apply structural modification that subsequently alters their functionalities. Enzymatic hydrolysis, as a "green" biological approach, has been extensively employed for this purpose. The aim of this study was to theoretically and experimentally investigate the effects of tryptic hydrolysis on the structure and surface adsorption of 11S legumin fraction (LR) with a particular focus on the effects of the degree of hydrolysis (%DH). The probability of the occurrence of all possible fragments was calculated first. Then, four dominant fragments (based on bulk volume fraction) were selected for conducting Self-consistent field (SCF) calculations. It was seen that 5% and 7% DH were beneficial for adsorption, generating a higher number of chains on the hydrophobic surface. Additionally, within the fragment mixture, we found clear evidence of competitive adsorption among compositional fragments, driven by differences in their primary sequence and surface configuration. In practical experiments, a series of physicochemical attributes of LR and its hydrolysates with %DH ranging from 1% to 12%, were investigated, such as protein composition, particle size, zeta potential, surface hydrophobicity and secondary structure. Following trypsin hydrolysis, the structure of LR (or aggregates) was effectively broken down, as evidenced by the emergence of lower molecular weight fractions and a reduction in colloidal particle size (from 270 nm to 119 nm). Moreover, 3-8%DH imparted a higher surface hydrophobicity and a more flexible structure, which are potentially beneficial to an enhanced surface binding affinity and bulk diffusion rate. The surface adsorption properties of LR and its hydrolysates were further evaluated by using Quartz Crystal Microbalance with Dissipation (QCM-D). Hydrolysates at 8%DH demonstrated superior performance, exhibiting the highest hydrated mass adsorption and film thickness (23.8 mg/m ^{2} and 21.6 nm, respectively). Additionally, the viscoelasticity of the adsorbed protein film was shown to vary with different %DHs, suggesting a more viscoelastic layer for hydrolysates at 3% to 8%DH. Interestingly, further hydrolysis led to a transition from a highly hydrated to a more rigid layer. Findings from this study could provide fundamental insights into tailoring plant protein surface adsorption via tryptic hydrolysis, paving the way for the application of plant-based hydrolysates in various surface-adsorption-related technologies, such as emulsions and foams.

Keywords:
Pea protein, Enzymatic hydrolysis, QCM-D, Self-Consistent Field (SCF) theory

Influence of Biopolymer, Algae and Plant-Based Additives on The Rheological Properties and Microstructure of Potato Purée.

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This study investigates the effects of both conventional hydrocolloids (agar, pectin) and natural biomass ingredients (*Scenedesmus* , *Ulva ohnoi* , *Portulaca oleracea*) on the microstructure and flow behavior of potato purée. Optical light microscopy revealed that each additive altered starch granule morphology and matrix organization in distinct ways. Agar and pectin formed stable gel structures that restricted starch leaching, whereas the bio-based microlalgal, macroalgal and plant additives introduced highly hydrophilic polysaccharides that facilitated granule expansion, disrupted structural cohesion, and increased amylose diffusion. Rheological profiling confirmed shear-thinning behavior across all samples. Viscosity responses varied with the source and dose of the additive—agar enhanced consistency, pectin displayed a non-linear pattern, and *Scenedesmus* and *Ulva ohnoi* modulated viscosity oppositely via extracellular polysaccharide and ulvan release. *Scenedesmus increased viscosity at higher concentrations whereas Ulva ohnoi decreased it. Portulaca oleracea* improved viscosity through mucilage-driven network formation. Thixotropic analysis indicated that 1% *Ulva ohnoi* produced the highest structural recovery. Collectively, these findings highlight the potential of natural polymers in fine-tuning textural and functional attributes in starch-based food formulations.

Keywords:
Alternative food source; Microscopy; Scenedesmus; Thixotropy; Ulva ohnoi; Viscosity; Yield stress.

Acknowledgements:
The authors would like to thank the predoctoral program AGAUR-FI ajuts (2025 FI-3 00065) Joan Oro, which is backed by the Secretariat of Universities and Research of the Department of Research and Universities of the Generalitat of Catalonia, as well as the European Social Plus Fund.

Suspensions and emulsions prepared with microalgae particles

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Microalgae particles have found applications in various food products. In this work we characterise these particles, and the effect that heat, pH changes, and shear have on them. In turn, we consider how these factors, as well as the interactions between these particles, contribute to the flow properties of microalgae suspensions. Finally, we study how using the microalgae particles can be used to tune the rheology and textural properties of food emulsions.

Keywords:
Microalgae, Rheology, CLSM, Suspensions, Emulsions.

Isolation and Characterization of Highly Pure RuBisCO from Alfalfa (Medicago sativa L.) for Food Applications

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Sustainable protein sources from green biomass are gaining interest as alternatives to conventional plant and animal proteins. Among them, the photosynthesis enzyme Ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCo) is considered a promising candidate due to its favorable amino acid composition and high digestibility [1]. RuBisCo can be isolated from regional green biomasses like alfalfa (*Medicago sativa* L.) [2] or sugar beet leaves (*Beta vulgaris* L.) [3], thereby adding value to agricultural by-products.
The aim of this study is to isolate RuBisCo from alfalfa plants in a highly pure form to further investigate its techno-functional properties in food applications. However, isolating highly purified proteins from green biomasses presents several challenges [4]. For example, rigid cell walls must be disrupted, which can release phenolic compounds and polyphenol oxidases that initiate enzymatic browning. Additionally, phenolic compounds and other secondary metabolites such as saponins and chlorophylls can cause undesired effects including bitterness, excessive foaming, and interactions with proteins. In addition, RuBisCo in higher plants is a large protein complex (approximately 550 kDa) that needs to be isolated in its native state to retain its full techno-functionality.
These challenges are addressed through an isolation approach that involves testing different pretreatments (e.g. blanching, addition of antioxidants) prior to juicing, followed by various juice treatments (e.g. chlorophyll coagulation, hexane extraction) and finalized by a chromatographic separation and polishing using HPLC with ion-exchange and size-exclusion steps. Isolation stages are monitored by Dumas and SDS-Page for protein content and composition, respectively, as well as polyphenol oxidase activity, the Folin-Ciocalteu assay for total phenolic content, and small angle x-ray scattering for structural identification.
Pretreatments effectively inhibit enzymatic browning during juicing, while the juice treatments significantly reduce the amount of accompanying compounds like phenolics and chlorophyll. During the ion-exchange step, proteins are clearly separated from other compounds. This protein fraction is subsequently polished by size-exclusion chromatography to obtain a highly pure RuBisCo isolate.
This study demonstrates a promising and efficient approach to obtain highly pure RuBisCo isolates, which can be further evaluated for their techno-functional properties, such as emulsion capacity in food applications.

Keywords:
RuBisCo, Isolation, HPLC, SAXS

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Compatibility and Gelation of Fucoidan–Alginate Systems Across Ionic and pH Conditions

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Fucoidan and alginate, two major polysaccharides in brown seaweed, play key roles in the structuring and hydration of cell walls. Understanding their interactions is essential for designing seaweed-inspired ingredients with tailored functionality in food systems. In this study, we investigated the compatibility, rheology, and gelation behaviour of binary fucoidan–alginate systems under varying physicochemical conditions. A comprehensive set of experiments examined the influence of pH, monovalent salts (NaCl and KCl), and calcium-induced crosslinking on viscosity, viscoelasticity, and gel strength. Rheological measurements revealed how ion identity and concentration modulate network formation and associative interactions between the two polymers. Structural characterisation using small-angle X-ray scattering (SAXS), FTIR spectroscopy, and optical microscopy provided insight into molecular organisation, intermolecular bonding, and microstructural heterogeneity.
The findings are discussed in the context of native seaweed cell-wall architecture, where alginate and fucoidan coexist within a complex matrix stabilised by multivalent cations. Our results highlight how their associative or independent behaviour depends on the ionic environment, ultimately shaping hydration, texture, and microstructure. From a food science perspective, these interactions inform the development of seaweed-derived hydrocolloids with specific thickening, stabilising, or gelling properties. By mimicking and tuning native polysaccharide assembly, fucoidan–alginate systems offer opportunities for clean-label structuring, salt-responsive textures, and functional diversification in plant-based formulations

Keywords:
Seaweed, rheology, structure, fucoidan, alginate

Structure–function relationships in plant proteins: from model systems towards clean-label plant-based ice cream

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In recent years, there has been a clear transition toward more plant-based diets. However, this shift appears to be slowing as the sector faces several headwinds. A major challenge lies in the typically inferior sensory quality of plant-based alternatives compared to animal-based products, while concerns about nutritional composition and the highly processed nature of many substitutes further limit consumer acceptance.
One important research focus has therefore been to understand how processing and purification influence the functionality of plant proteins as food ingredients. The composition of legume and oilseed protein isolates, for example, can vary in their legumin-to-vicilin (L:V) ratio. In pea, the L:V ratio ranges from 66:33 to 10:90 (w/w), depending on the cultivar [1-6]. In our studies, we investigated how this ratio affects emulsifying and foaming properties of pea protein isolates at neutral pH and low ionic strength (pH 7.0, ~20 mM sodium phosphate) [7] and under more realistic food conditions (pH 4.8, McIlvaine buffer + 200 mM NaCl). The results showed that at pH 7.0, pea legumin and vicilin exhibit similar emulsifying properties, whereas at pH 4.8 they do not. The effect of the L:V ratio may be exploited in food product development through the selection or breeding of pea varieties exhibiting a desirable ratio.
Building on this mechanistic understanding, our current research explores how composition and processing affect the sensory properties of clean-label plant-based ice cream, a product type often perceived as less creamy and flavorful than the dairy-based version. In collaboration with a Michelin-starred restaurant, an ice cream producer, and a plant-based ingredient manufacturer, we employ a Design of Experiments (DoE) approach to systematically examine how formulation and processing influence sensory perception. Evaluations by expert and consumer panels will link food structure to sensory experience. This work aims to provide a scientific foundation for the rational formulation of plant-based ice creams that combine desirable texture and flavor with clean-label and sustainability standards.

Keywords:
plant-based, protein, functionality, emulsion, foam, ice cream, sensory, colloids, clean-label

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Freeze structuring enables texturization of legumes for accessible and scalable food products

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Legumes are a sustainable, nutrient-rich, and affordable food source, yet their full potential remains underutilized due to limitations in conventional processing methods, which often fail to incorporate the whole raw material or produce desirable textures. Here, we present freeze structuring (FS) as a versatile and gentle technique to impart texture to legume-based foods. By combining unidirectional freezing, which promotes anisotropic, fibrous structures, with freeze concentration to enhance gelation, we demonstrate that whole-legume suspensions can be transformed into structured gels without the need for raw material purification or additives.
Applied to chickpeas, FS produced gels with increased hardness and pronounced visual and textural anisotropy compared to their fridge-cooled control, indicating the method's potential to generate meat-like structures and textures. Extending the approach to a variety of widely consumed legumes revealed broad applicability across diverse compositions. This work positions FS as a scalable, accessible strategy for creating innovative, clean-label legume products using standard freezing technologies, with relevance to both domestic and industrial food production.

Keywords:
Freeze structuring, legumes, plant-based, food colloids, anisotropic structure, food structuring, food texture, meat analogues

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Modulation of the functional behavior of fava bean flour through processing

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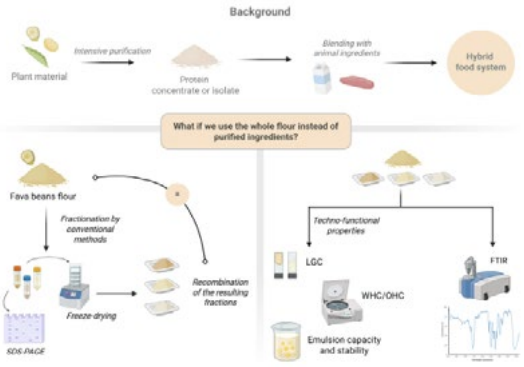
Developing **hybrid food systems** (animal and plant-based ingredients into a single food) requires plant ingredients with excellent techno-functional properties that support stable colloidal structures. Current research on hybrid formulations relies mainly on protein isolates or concentrates, typically involving **intensive purification** that can compromise sustainability, while the potential of flours from the whole crops is still largely unexplored.
This study addressed a critical question: does **unprocessed fava bean flour** have superior properties over **conventionally processed ingredients** ?
To answer this, fava beans were fractionated using conventional methods, including **alkaline extraction** at pH 8.5 or 10.5 combined with isoelectric precipitation, and **saline extraction** . SDS-PAGE has been carried out to monitor the protein profiles of the different fractions throughout the process, and it showed that extraction treatments precipitated the globulins (major storage proteins) at acidic pH, while retaining the soluble albumins (minor storage proteins). All resulting fractions were saved, freeze-dried and subsequently **recombined** to reconstitute the original fava bean flour and eliminate the effect of composition. Milled dehulled fava beans and the three recombined fava bean flours were compared in terms of their techno-functional properties and protein secondary structure (FTIR).
FTIR spectroscopy first revealed that the treatments induced significant modifications in the protein secondary structure of the recombined flours compared to the original. Compared to the unprocessed flour, the recombined flours exhibited, at 95 °C, a lower least gelation concentration (5% vs 7.5% w/w), higher water and oil holding capacity (at least 2.18 g/g vs. 2.03 g/g for WHC and at least 1.83 g/g vs. 1.24 g/g for OHC), and enhanced emulsion stability, highlighting the potential of processing-induced modifications for manufacturing improved ingredients based on whole fava beans.
In conclusion, this study demonstrates that fava bean flours modified through conventional processing can be potential ingredients for developing hybrid systems, thereby creating a value-added system with no side streams and suggesting a promising pathway towards more **sustainable processes** . Our future work will investigate even simpler methods, such as direct pH shifting of the dispersion, to better understand the molecular and colloidal changes during the fractionation. Analysis of the acid-induced gelling properties and microstructural characterization will complete the picture and pave the way for novel plant-dairy hybrid yoghurts.

Keywords:
Unprocessed fava bean flour, fractionation, techno-functional properties, hybrid food systems



Graphical abstract: background and methods

Engineering Interfacial Interactions in Pea Protein Colloids for Enhanced Functionality and Flavour

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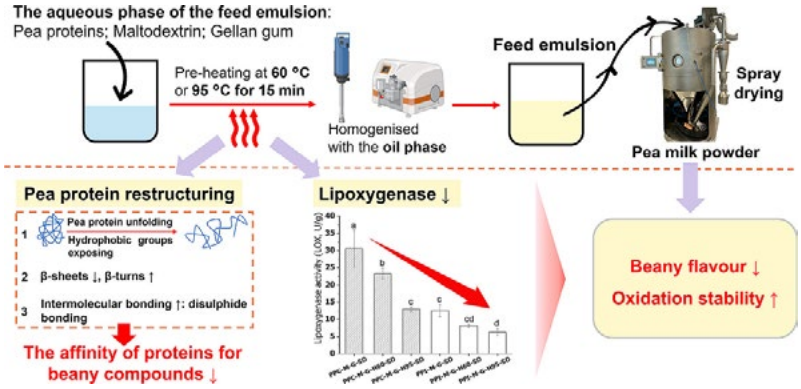
The development of plant-based colloidal systems relies on the ability to tailor protein–polysaccharide interactions for improved stability, digestibility, and flavour. This work presents a comprehensive investigation into the structural and functional modulation of pea protein emulsions and powders through interfacial engineering and thermal processing [1]. Using model pea milk systems, we demonstrate that combining pea protein isolates or concentrates with gellan gum significantly enhances oil–water interfacial adsorption, forming thicker viscoelastic layers that resist coalescence and improve proteolytic accessibility during gastrointestinal digestion [2]. Pre-roasting of pea seeds (150 °C, 10–20 min) and aqueous-phase pre-heating of feed emulsions (60–95 °C) prior to spray drying induce protein unfolding (↓ β-sheets, ↑ β-turns, ↑ surface hydrophobicity), reduce lipoxygenase activity, and mitigate beany flavour compounds such as hexanal and 1-octen-3-ol [3-4]. These structural transitions also improve emulsifying activity and oxidative stability in pea milk powders [4]. Understanding the changes in structural and interfacial properties of pea protein under targeted treatments enables the design of scalable processing for legume-based colloids with enhanced functionality for diverse food applications.

Keywords:
Pea protein, Interfacial engineering, Plant-based colloids, Beany flavour mitigation



Schematic illustrating the impact of pre-heating to reduce the affinity of pea proteins for beany compounds [4]

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Acknowledgements:
This project was supported by Australian Research Council (ARC) Discovery grant (DP200100642). The authors would like to acknowledge access to the shared facilities at Mark Wainwright Analytical Centre, UNSW.

Processing–Structure–Function Relationships in Lentil Protein-Stabilised Emulsions: Unravelling Colloidal Mechanisms for Infant Formula

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The growing demand for sustainable and nutritionally balanced plant-based foods drives the need for processing innovations that improve the techno-functional properties of plant proteins. This study investigates the effects of physical processing techniques on lentil protein-stabilised emulsions at high total solids, aiming to enhance their techno-functional properties and colloidal stability for use in young child nutritional products.
Lentil protein emulsions were formulated using lentil protein, sunflower oil, and maltodextrin (15.85%, 27.43%, and 56.72% of total solids, respectively). The emulsions demonstrated high physical and thermal stability at moderate total solids (23–26%), while at higher total solids ($\geq$ 29%) exhibited poor stability, characterized by extensive oil droplet flocculation. Limited protein solubility in these high-solid systems was identified as a key factor restricting the techno-functional performance of the emulsions.
To address this limitation, different physical pre-treatments were applied to lentil protein dispersions. High-shear mixing increased solubility from 46.87 to 68.42% after 15 minutes at 15,000 rpm, and increased physical stability, reducing separation rates from 71.23 to 24.16%·h^{-1}. High pressure homogenization (HPH) proved more effective, significantly enhancing solubility up to 96.4% at 150 MPa.
HPH was therefore selected for further investigation, and lentil protein dispersions were subjected to HPH at pressures ranging from 0 to 150 MPa prior to emulsion preparation at high total solids (29% w/w). Increasing homogenisation pressure significantly improved lentil protein solubility, from 55.7 to 93.2% at 0 at 50 MPa, respectively, consistent with molecular unfolding and the disruption of insoluble aggregates [1]. These structural changes enhanced protein adsorption at the oil-water interface, leading to a reduction in $D_{4,3}$ from 1.40 μm (0 MPa) to 1.19 μm (150 MPa). Consequently, emulsion stability increased markedly, with phase separation rates decreasing from 16.75 to 2.05%·h^{-1}. Rheological assessment revealed that HPH-treated emulsions exhibited lower viscosities, both before and after thermal treatment (90°C, 2 min), indicating improved stability to heat-induced flocculation. Confocal laser scanning microscopy confirmed a more homogeneous droplet distribution and reduced aggregation following HPH pre-treatment, reflecting the formation of a more cohesive and elastic interfacial protein network at the oil-water interface [2].
Further investigation of combined HPH (50 MPa) and thermal treatment (120 °C for 60 s) revealed synergistic effects; protein dispersions exhibited higher solubility (up to 96.4%), smaller particle size (from 10.7 to 0.27 μm), and increased physical stability (from 8.12 to 4.97%·h^{-1}). Emulsions formulated under these conditions showed substantially enhanced heat and physical stability at high total solids (29% w/w), maintaining integrity during thermal processing with minimal flocculation and lower viscosity (from 19.18 to 7.43 mPa·s).
Overall, the results demonstrate that HPH is an effective pre-treatment that enhances the solubility, interfacial behavior, and thermal stability of lentil protein in high-solid emulsions, offering mechanistic insights and supporting the development of sustainable, plant-based infant nutritional products. This work provides new mechanistic insights into the relationship between protein solubility, structural modification, and interfacial functionality under dynamic processing conditions.

Keywords:
lentil proteins, solubility, colloidal stability, rheological properties, infant formula.

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Sequential precipitation strategy for fractionating pea globulins into legumin, vicilin, and albumin: A comparison with isoelectric precipitation

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Background: The functional properties of pea proteins depend on their processing history. The traditional alkaline extraction-isoelectric precipitation (IEP) separates pea globulins in one step, resulting in an isomer mixture of legumins and vicilins. These isomers have a broad range of isoelectric points (pI) which may lead to discrepancies across studies and inconsistent techno-functional properties. The aim of this study is to understand the potential differences in protein composition, structure, and functionality of legumin and vicilin fractions in globulins precipitated at different pH levels.
Methods: For the IEP method, pea protein concentrate (PPC) was dispersed in water at pH 9. IEP globulins were collected at pH 5. For the sequential precipitation, PPC was dispersed in water at pH 7, and then pellets were collected stepwise at pH 7, 6, and 5 (Figure 1). Globulin pellets from both methods were then further fractionated into legumin- and vicilin-enriched fractions. Protein compositions were characterized by SDS-PAGE. The protein content and recovery of fractions were measured using Dumas. Asymmetric flow field-flow fractionation with multi-angle static light scattering and refractive index (AF4-MALS-RI) is applied to compare the purity and corresponding molar mass of fractions obtained from different extraction methods. Dynamic light scattering will be used to measure the pI of various fractions. The secondary structure will be characterized by FTIR and the thermal properties will be measured using NanoDSC.
Preliminary results / Expected outcome: Sequential precipitation at pH 6 resulted in the highest protein content (protein factor: 5.4) of legumin (86.1%) and vicilin (78.9%) fractions, slightly higher than IEP (pH 5) legumin and vicilin. Lower protein content after precipitation at pH 7 or pH 5 suggest that proteins and other components may interact. The overall yields were highest at pH 6, and low at pH 7 and pH 5. By comparing the total recovery of legumin (19.8%) and vicilin (26.6%) in the sequential precipitation method to that of the IEP method (legumin: 20.9%, vicilin: 17.9%), we found that more vicilins were fractionated in the sequential precipitation method. The recovery of albumins (14.8-13.1%) and legumins (19.8-20.9%) in both methods are comparable. It is expected that legumins and vicilins precipitated at different pH levels have distinct pI values, indicating that they may have distinct protein composition, surface properties, and conformational properties, which will further influence their techno-functionalities.
Significance: Understanding the differences among the pea protein isomers with distinct pI values will provide mechanistic insights to optimize the extraction and functional utilization of pea proteins.

Keywords:
Pea protein, legumin, vicilin, albumin, fractionation, characterisation

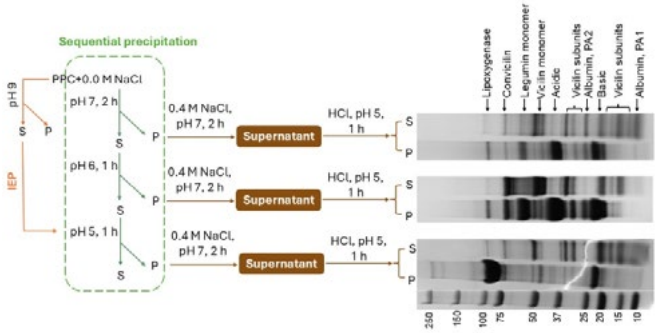

Figure 1. The pea protein extraction process using traditional isoelectric precipitation (IEP) method and the sequential precipitation method, showing the composition of the fractions using non-reducing SDS-PAGE. S stands for supernatant and P for pellet.

Acknowledgements:
Lantmännen Research Foundations are acknowledged for financial support.

Sequential Cross-Linking Modulates Pea Protein Gelation: Effect of pH and Salts

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Plant proteins are increasingly used to structure food systems, yet forming solid-like gels remains challenging. This study investigates how sequential cross-linking – the order of acidification and salt addition – affects the gelation of high-protein emulsion gels made from commercial, soluble pea protein.
Two salts, NaCl and $CaCl_2$, and final pH values of 3 and 6 were evaluated, adjusted from the protein's native pH of ~8. Following protein characterization, emulsion gels were prepared and analyzed using oscillatory rheometry, including time, frequency, and amplitude sweeps. Image analysis was used to assess gel microstructure.
When pH was acidified to 3 prior to salt addition, gels exhibited significantly higher stiffness compared to the sequence where salt was added before acidification. This enhancement is likely due to increased electrostatic repulsion at low pH, enhancing protein solubility and enabling more effective charge screening and protein–protein interactions due to salt addition. Conversely, adding salt first likely caused irreversible salting-out, hindering network formation even after acidification. At pH 6, trends were similar but less pronounced, possibly due to reduced net charge near the isoelectric point (pI ≈ 5), reducing the influence of salt.
These findings demonstrate that the sequence of acidification and salt addition influences gel network formation. Acidification to pH 3 prior to salt addition can offer a clean-label strategy to enhance gel strength and texture in plant-based formulations.

Keywords:
plant proteins, commercial isolates, emulsion gels, food structuring

Colloidal behavior of faba bean 7S and 11S globulins under varying pH and ionic strength

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The colloidal state of plant proteins in aqueous dispersion, which plays a decisive role in their functional behavior, strongly depends on environmental factors such as pH and ionic strength. However, this remains poorly understood for many plant proteins, including faba bean protein (*Vicia faba*), an increasingly important alternative protein source. This study investigates the effect of **pH and ionic strength** on the **colloidal state** of **7S and 11S globulin-enriched fractions** and a **faba bean protein isolate (FBPI)** , obtained through aqueous extraction followed by isoelectric point precipitation.

A combination of turbidity, light scattering, and confocal laser scanning microscopy measurements revealed **microphase separation** in the FBPI within a narrow pH range (7.2-6.6). Interestingly, these protein-rich domains were shown to behave as liquid-like droplets, with their size and abundance increasing from 20 to 100 mM NaCl, before decreasing again at 200 mM NaCl. At lower pH (3.0-6.6), these droplets were observed to progressively transition into a more solid, sticky state, forming clusters of spherical, gelled droplets.

Overall, relatively small protein-rich domains (< 2.0 μm) were obtained for FBPI under all conditions mentioned. Interestingly, 11S globulin showed more extensive phase separation with larger domains (8 μm) under the same condition (pH 6.8, 50 mM NaCl, 1.0% w $_{protein}$ /v), whereas the 7S globulin fraction showed similar behavior as the typical protein isolate. This indicates, for the first time, that **7S globulins inhibit the formation of bigger droplets by 11S globulins** due to interaction between both protein types. Ongoing work will further investigate the protein composition and interaction between both protein types, providing novel insights into the colloidal state of faba bean protein.

Keywords:
colloidal state, faba bean protein, effect of pH and ionic strength

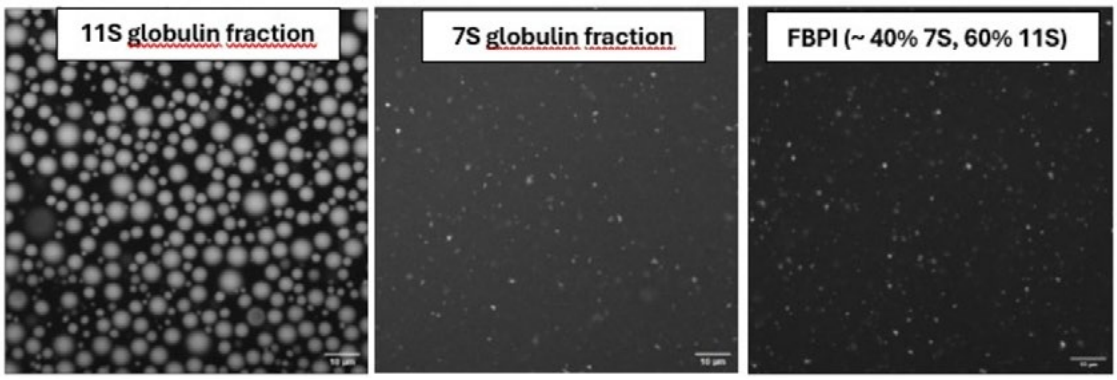

Figure 1: Confocal laser scanning microscopy images showing microphase separation for FBPI, 7S, and 11S globulin-enriched fractions under the same conditions (pH 6.8, 50 mM NaCl, 1.0% wprotein/v).

Boosting juiciness and flavor perception of meat analogue patties by altering hydration level and particle size of textured vegetable proteins

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Current meat analogues often lack the desired mouthfeel to compete with meat, especially in terms of juiciness. Achieving desirable juiciness in plant-based meat analogues (PBMA) requires control over water retention after cooking and water release upon mastication, also referred to as the serum. Such water distribution is mainly affected by the characteristics of the textured vegetable protein (TVP), which is able to absorb and retain water in its porous structure. We examined how textured vegetable protein (TVP) hydration level and TVP particle size affect such water distribution, and specifically how it affects PBMA composition, mechanical properties, and serum (liquid) release during consumption. Serum release during compression was analyzed analytically using a custom-built device. To understand the relationship between different PBMA characteristics and specific sensory attributes, a RATA methodology was used. As expected, higher TVP hydration increased total initial water content and cooking loss. However, most of this water still remained after grilling of the meat patties, which provided a more moist and softer product. The additional retained water coincided with a higher serum (liquid) release under compression.
The greater serum release led to elevated perceived juiciness and fattiness and reduced hardness and crumbliness. These mechanical properties were also affected by particle size; larger particles yielded firmer, chewier patties. In addition, larger particles also reduced serum release. Correlation analysis using an undirect graphical model (UGM) indicated that juiciness was associated with serum release and with lower Young's modulus. Fattiness showed a similar association pattern, but was shown not to be related to the fat content of the cooked patties. These results show that mesoscopic structuring via TVP hydration and particle size provides a practical route to tune water retention and release dynamics in PBMA and, consequently, can improve juiciness.

Keywords:
plant-based meat analogues, textured vegetable protein, juiciness, serum release, structure–function relationships

Valorization of oil extraction side streams of microalgae as emulsifiers and foaming agents

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Microalgae are an emerging source of nutrients including oils due to their sustainable production which is not competitive to other resources. Oils produced from microalgae can be used either for nutritional purposes for humans, animals and fish or for the production of biodiesel. The oil use depends on the species, since certain species are allowed for nutrition, as well as on the processes and other resources (e.g. oil extraction chemicals, microalgae cultivation parameters). In the same manner the side streams of microalgae oil extraction can be valorized. This work examines the potential of valorizing the side streams produced from oil extraction as emulsifiers and foaming agents. The idea for this stems from the fact that the side streams are rich in proteins, phospholipids and potentially other polar lipids [1] all being good candidates as emulsifiers and foaming agents. The goal here is not to produce a purified form of compounds but rather to examine whether the side streams obtained using different oil extraction approaches can be applied as emulsifiers or foaming agents as they are or with mild processing so as to propose economic and easily applicable solution for the food industry.

Keywords:
foaming agents, emulsifiers, microalgae

References:

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Acknowledgements:
Funded by the European Union under the project Fuelphoria. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor CINEA can be held responsible for them.

The Effect of Extraction Conditions on the Composition and Foaming Properties of Wheat Bran Proteins

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Wheat bran is an underutilised source of aqueous phase-soluble proteins with a well-balanced amino acid profile and promising functionality for plant-based foods. Exploiting these proteins requires insight into how extraction conditions affect their composition and interfacial behaviour. Aqueous extractions over a range of pH values revealed that alkaline conditions promoted high protein recovery but co-extracted lipids and produced turbid extracts, whereas acidic conditions yielded clearer, protein-poor extracts enriched in ash and phytic acid. Size-exclusion chromatography revealed that alkaline extraction favoured larger proteins such as glutenins and globulins, while acidic extraction enriched smaller proteins, including albumins and peptides. Isoelectric precipitation at pH 9.0 increased protein purity but reduced dispersibility due to aggregation. Foaming tests demonstrated that alkaline extracts formed large amounts of stable foam, comparable to conventional reference plant proteins, whereas isolates obtained by isoelectric precipitation generated lesser amounts of less stable foam, likely due to protein aggregation and the presence of high amounts of lipids. Pendant drop tensiometry confirmed a faster reduction in surface tension for the alkaline extract, consistent with its superior foaming capacity. Overall, these findings highlight the potential of wheat bran proteins as sustainable functional ingredients for aerated and other colloidal plant-based food systems.

Keywords:
Wheat Bran, Plant Proteins, Protein extraction, Foaming, Interfacial Activity, Colloidal Systems

Valorization of pumpkin seed press cake via optimized alkaline extraction and functional improvement of proteins.

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The valorization of side-streams has become an important focus within the food industry, aiming to transform by-products into ingredients with increased value, suitable for reintroduction into the food market. In this study, the focus was placed on investigating the potential of pumpkin seed press cake, a by-product of pumpkin seed oil production as a source of functional proteins. Even though the substrate is rich in protein (65%), its intense thermal processing history (roasting, pressing) leads to poor solubility of the extracted protein. This work focused on optimizing alkaline extraction conditions to maximize protein yield and additionally on improving protein solubility. Extraction parameters, including temperature, time, and NaOH concentration, were systematically varied, achieving protein yields of up to 56% using 0.2 M NaOH. Prolonged extraction time and elevated temperature (50°C) significantly enhanced both yield and protein solubility. Under optimal conditions (0.2 M NaOH, 50°C, 4 h), solubility reached approximately 35% at pH 7 and the solubility curve as the only one measured nearly reaching its plateau at pH 10 with about 85% solubility. To further modify the functionality and improve solubility at pH 7, high-pressure homogenization (HPH) was applied in three cycles as a post-extraction treatment, using pressures of 30, 60 and 90 MPa. Consequently, the particle size decreased from 5–10 μm to 100–1000 nm. The results of SDS-PAGE showed that performing HPH at the given pressure did not result in any significant changes to the protein profile. Samples treated with HPH showed increased solubility, with an enhancement of up to 30% at pH 7. These results demonstrate that alkaline extraction combined with HPH represents a simple yet effective approach to upgrade thermally stressed side-stream materials, supporting the broader goal of sustainable resource utilization and protein circularity in the food industry. Future research will aim to elucidate the structural and interfacial properties of the extracted proteins to better understand the mechanisms underlying their improved functionality and potential applications in complex food matrices.

Keywords:
Plant protein, Alkaline extraction, post-extraction modification, protein solubility

From by-product to functional ingredient: Upcycling of currant pomace for fibre enrichment and emulsion stabilisation

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By-products from fruit processing, such as currant pomace, are currently rarely integrated into human consumption. Zero-waste concepts aim to amend this by encouraging a nearly complete utilisation of these by-products and their fractions (seed and fibre fraction) in e.g. food systems. So far, the valorisation of currant pomace has mainly focused on the extraction of polyphenols, antioxidants and lipids. However, currant pomace also contains proteins that may contribute to meeting the demand for sustainably sourced protein and may be exploited for their techno-functional properties, e.g. as emulsifiers. Furthermore, currant pomace has a high dietary fibre content (approximately 60%), additionally offering an opportunity to enrich food and support the recommended daily fibre intake.

Despite this potential, enrichment with dietary fibre is very often associated with changes in structural and rheological properties of a food product, which is a limitation in soft and smooth foods like drinks, desserts and yoghurt. To overcome this limitation, we applied a thermo-mechanical pre-treatment of the pomace to reduce the particle size of the fibre and to increase the proportion of soluble dietary fibre. Upon incorporation of the pre-treated fibre in yoghurt, the pre-treatment slowed the sedimentation of fibre particles during fermentation and facilitated their incorporation into the milk protein network. Furthermore, there was no negative impact on the rheological properties of the yoghurt, syneresis was decreased and a claim as a source of dietary fibre (3 g/100 g) under European law would be possible.

Regarding the use of the protein fraction of the currant pomace as an emulsifier, we used the protein-rich seed fraction and applied an extraction protocol at different pH values and found that under acidic conditions mainly albumins with high molecular mobility and surface hydrophobicity were extracted, while a broad spectrum of proteins (mainly storage globulins) with a higher surface charge were extracted at a neutral pH. Investigation of the interfacial and emulsifying properties of these protein fractions showed that the proteins present in the albumin-rich extracts formed an interfacial film via hydrophobic interactions which was stable against coalescence. In contrast, the globulin-rich extract was prone to increasing bridging flocculation, resulting in a gel-like state of the emulsions.

Moreover, the presence of proteins and fibres in emulsions, achieved by using a pre-treated fibre fraction, enables additional particle-based stabilisation. Oil-in-water emulsions could be produced with an addition of 5% fibre fraction regardless of the oil content (10%, 30% or 50%).

Overall, our results highlight the wide potential of utilising proteins and dietary fibre from currant pomace for the formulation of more sustainable food products and in the context of implementing a zero wate concept.

Keywords:
by-products, utilisation of side-streams, sustainability, disperse system, rheological properties, plant-based emulsifier

Acknowledgements:
This IGF Project (AiF 20917 BG) of the FEI was supported within the programme for promoting the Industrial Collective Research (IGF) of the Federal Ministry of Economic Affairs and Climate Action (BMWK), based on a resolution of the German Parliament.

Ultrasound-Assisted Extraction and Colloidal Properties of Protein Isolates from Neglected Sicilian Black Chickpeas

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The valorization of underutilized legume varieties supports biodiversity and enhances food system sustainability, while offering plant-based protein ingredients with distinctive structural and colloidal functionality suitable for tailored food applications. This study investigated the extraction, physico-chemical, and functional properties of protein isolates obtained from two neglected black chickpea (*Cicer arietinum* L.) cultivars, originating from Sicily, in southern Italy. These varieties, which were abandoned over time due to their dark color and lengthy preparation time, are today reconsidered for their tolerance to drought and high temperatures, underscoring their importance in the context of climate change.
Flours were first characterized by their proximate composition and total phenolic content. Protein extraction was subsequently performed by comparing a conventional alkaline method with an ultrasound-assisted (US) process, applying three different sonication times. Protein recovery, purity, and yield were quantified to assess extraction efficiency and process scalability. The obtained protein isolates were then characterized to investigate their structural and colloidal properties. Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) was performed in order to determine the protein profile. The secondary structure was examined by Fourier-transform infrared spectroscopy (FT-IR), while thermal stability was assessed by differential scanning calorimetry (DSC). The particle size distribution and ζ-potential were evaluated by dynamic light scattering (DLS) to investigate their colloidal behavior and stability. Model oil-in-water emulsions were then prepared using the protein isolates as emulsifying agents, and the droplet size distribution and emulsion stability were analyzed using a Mastersizer 2000 particle size analyzer, and ζ-potential to evaluate interfacial activity and aggregation behavior over time. The flours exhibited a protein content of approximately 20% and a phenolic content ranging from 62 to 67 μg GAE/mL. The US-assisted method enhanced the protein extraction yield by 20–27% and the protein recovery yield by approximately 17–23% compared to conventional alkaline extraction. The protein isolates showed high purity (85–91%), high solubility (74–94%), and promising colloidal stability as emulsifier in food applications.

Keywords:
Black chickpea; Protein isolates; Ultrasound extraction; Colloidal functionality; Emulsifying properties; Plant-based proteins.

Effect of fermentation on the properties of a plant-based cheese formulated with faba bean protein

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Interest in plant-based products has been growing rapidly as consumers seek more sustainable and ethical protein sources [4]. Legume proteins, particularly those from faba beans, represent a promising option due to their high protein content and nutritional value. However, one of the main challenges in developing plant-based alternatives to meat and dairy products [5] lies in improving the gelling properties of these proteins. This is especially relevant for plant-based cheese substitutes, a rapidly expanding market projected to grow from 584 million euros in 2025 to 1.83 billion euros by 2035.
In legumes, it has been shown that fermentation enhances digestibility [1] and improves techno-functional characteristics [2]. When applied to plant-based gels, fermentation may induce proteolysis, altering protein interactions and network formation—ultimately influencing texture development in a way similar to cheese ripening.
This study aimed to examine how fermentation with lactic acid bacteria differing in proteolytic activity affects the composition, structure, and texture of a plant-based gel over time. Tests were conducted from production to 4 weeks to assess the impact of progressive protein degradation and the formation of new compounds on the gel network, potentially enhancing its functionality as observed in semi-hard cheese.
In the present work, a 90% faba bean protein isolate was used to prepare a 5% protein solution. Then, 5% of sunflower oil was added to form a stable submicronic emulsion under high pressure homogenization at 50 MPa. A thermal treatment at 125 °C was applied to sterilize the solution, and the resulting "faba bean milk" was stored at 4 °C. After addition of 0.5% NaCl and 5 g/L glucose, the gelation of the protein system was obtained by adding approximately 10^7 UFC/mL such as *Lactococcus lactis* , *Streptococcus thermophilus* and *Lactobacillus delbrueckii* - selected for their proteolytic activities - and 20 mM $CaCl_2$ and heating it at 40 °C for 2 h. The resulting smooth gel was cut in pieces to facilitate draining and pressed
Textural and structural parameters of the resulting faba bean-based gel were investigated. Development of the different bacteria populations in the gel during ripening was followed by counts on petri dishes filled with specific media. Texture of the resulting ripened gels was analysed through texture profile analysis (TPA), compliance test, and dynamic rheology. The modification of the proteins due to proteolysis was followed by OPA method and electrophoresis (SDS-PAGE). These tests provided a better understanding of the structural modifications occurring in the gel. While OPA results showed higher values for gels fermented with lactic acid bacteria known for their higher proteolytic activity, cohesiveness decreased by 5 to 10%. This means a loss of initial structure recovery after a deformation, following a similar trend to that observed in semi-hard cheese during ripening. On mesostructure, a higher viscosity, and a lower relaxation time for gel with a longer ripening duration attested of a higher mobility of its network. Dynamic Mechanical Thermal Analysis (DMTA) led from 70 to 110 °C also showed that the loss factor (tan(δ)) was increasing with temperature from 0.25 to 0.4 on proteolyzed gel, which indicates a change to a more viscous-like material. This could be explained structurally by an increase in the formation of hydrogen bonds that are more sensitive to high temperature and could appear with proteolysis [3]. This work highlights the need to understand how each component used in the process influences the network formation and texture, to better model faba bean protein functionality.

Keywords:
Faba bean, Protein, Gel, Fermentation, Texture

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EFFECTS OF ENZYMATIC, ACIDIC AND BASIC HYDROLYSIS ON LUPIN EXTRACTS

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Natural plant extracts have the potential to become effective surface-active agents. Although plants contain significant amounts of storage proteins, these proteins do not exhibit sufficient surface activity required for effective surfactants. Lupin, a high-protein plant currently used for food and feed purposes, is such an example. Extracts obtained from this plant, when subjected to appropriate modifications, can serve as natural surfactants and be applied in the food, cosmetic, or pharmaceutical industries.

Twenty extracts were obtained from narrow-leafed lupin (Lupinus angustifolius, cultivar OSKAR) seeds. The extracts were prepared by mixing lupin pellets with water for either 3, 5 or 24 hours. The first group of extracts was produced by varying the temperature and pH to create suitable conditions for protein hydrolysis. The second group was obtained with the addition of cellulolytic and pectolytic enzymes at different concentrations. All extracts were spray-dried and analyzed for protein content using elemental analysis as well as the Lowry and Bradford methods. The sugar content was determined by the Luff–Schoorl method, while the degree of hydrolysis was assessed using the OPA method. Solutions of the extracts were further analyzed for surface tension and surface rheology using a tensiometer.

In the conducted studies, it was observed that the extraction yield increased with rising temperature during the extraction process. The protein content in the obtained extracts varied depending on the applied method, with the highest value recorded for the sample subjected to alkaline hydrolysis. Analysis of surface properties showed that the addition of enzymes resulted in a decrease in surface tension, indicating an improvement in the surface activity of the extracts. Furthermore, enzymatic modification led to an increase in the reducing sugar content of the extracts, which may indicate the occurrence of polysaccharide hydrolysis. A higher degree of protein hydrolysis was observed for samples produced under elevated temperatures and acidic conditions.

Keywords:
plant extracts, lupin, hydrolysis, proteins

Acknowledgements:
This work was supported by the National Science Centre, Poland, under the project no. 2024/53/B/ST4/00261.

Stabilization of oil-in-water Pickering emulsions with plant protein-based particles obtained by electrospraying

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Pickering emulsions are attracting substantial scientific interest owing to their superior resistance to physical destabilization mechanisms. This enhanced stability arises from the fact that once colloidal particles are adsorbed at the oil–water interface, their desorption requires significantly greater energy compared to that of conventional molecular emulsifiers. Particularly interesting is the development of Pickering particles from sustainable biopolymers. In this regard, highly hydrophobic plant proteins such as prolamins have been generally reported for the efficient stabilization of food-grade oil-in-water Pickering emulsions. Thus far, antisolvent precipitation remains the most extended method to produce prolamin-based particles. Nevertheless, electrospraying, which allows the drying at room temperature by applying an electrostatic field, is a more versatile technique allowing the production of both isotropic and anisotropic colloidal particles from sustainable biopolymers.
This work aimed at investigating the development of plant protein-based particles by electrospraying and their performance in the formation and stabilization of oil-in-water Pickering emulsions. First, isotropic particles were produced by monoaxial electrospraying using zein or kafirin. Secondly, anisotropic particles were obtained either by i) monoaxial electrospraying of one solution containing both zein and kafirin or ii) by simultaneous electrospraying (co-jetting) of two different solutions (a) zein and (b) kafirin. The electrosprayed particles were characterized in terms of size and morphology and their interfacial activity was assessed by measuring interfacial tension and dilatational rheology in linear and non-linear deformation. Finally, the physical stability of oil-in-water Pickering emulsions stabilized with the obtained particles was studied by determining droplet size distribution, zeta potential and creaming during storage.
The results demonstrate that electrospraying is a promising technique for the development of bottom-up colloidal particles from sustainable sources, which exhibit techno-functional capabilities as Pickering emulsion stabilizers.

Keywords:
Electrospraying; Zein; Interfacial tension; Dilatational rheology

Acknowledgements:
This project was funded by BBVA Foundation - Leonardo Grants for Researchers and Cultural Creators 2023. The authors also acknowledge projects PID2023-146901OB-I00, PID2023-149387OB-I00 and PID2023-147135OB-I00 funded by MICIU/AEI/10.13039/501100011033 and by FEDER, EU. MAFR acknowledges an EMERGIA grant with reference EMC21_00008, and projects C-ING-208-UGR23 and C-EXP-187-UGR23 co-funded by Consejería de Universidad, Investigación e Innovación de la Junta de Andalucía, and by FEDER "Andalucía 2021-2027".

Antimicrobial activity of Chitosan coating containing Olive Oil Pomace extract against E. coli O157:H7 on fresh-cut carrots

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In recent years, *E. coli* has been linked to numerous foodborne outbreaks associated with the consumption of contaminated fresh produce including carrots. This study aimed to investigate the minimal inhibitory concentration (MIC) and minimal bactericidal concentrations (MBC) of olive oil pomace (OOP) extract against 4 strains of *E. coli* O157:H7 using a microdilution assay, and evaluate the antimicrobial activity of OOP extract incorporated in chitosan against *E. coli* O157:H7 on fresh-cut carrots. OOP extract was prepared using 100% ethanol, and the chitosan coating solution was prepared at a concentration 1% (w/v). Then, two different concentrations of OOP extract (12% and 18%) were added to chitosan. Five treatments (control without washing, control with washing, chitosan only, chitosan containing 12% OOP extract, and chitosan containing 18% OOP extract) were prepared and applied on *E. coli* O157:H7-inoculated fresh-cut carrots that stored at 4 or 10 °C for 10 days. The MIC and MBC of the OOP extract were 125 and 250 mg/ml, respectively, against all *E. coli* O157:H7 strains tested. At the end of the storage period at 4°C, chitosan coatings containing 12% and 18% OOP extract reduced *E. coli* O157:H7 by 3.5 and 3.7 log, respectively, compared to control samples without washing, and reduced *E. coli* O157:H7 by~ 1.0 and 1.3 log, respectively, compared with samples coated with only chitosan. At 10°C, chitosan coatings containing 12% and 18% OLP extract reduced *E. coli* O157:H7 by 2.4 and 2.7 log, respectively, compared to control samples without washing. These findings suggest that incorporation of OOP extract in chitosan coating has promising antimicrobial properties, indicating its potential use as a natural antimicrobial agent to enhance the safety and shelf life of fresh produce.

Keywords:
food Safety, Packaging, Food Waste, Antimicrobial coating

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Acknowledgements:
The authors thank PRIMA Foundation, The Higher Council For Science And Technology (HCST), and The Hashemite University for financing this work

COLD PLASMA PROCESSING AS A STRATEGY TO IMPROVE THE TECHNO-FUNCTIONAL PROPERTIES OF CASHEW NUT PROTEIN CONCENTRATES

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In recent years, the food industry is increasingly prioritizing innovative processing technologies capable of producing high-quality ingredients through environmentally friendly processes **[1]** . Among these, cold plasma (CP) processing has gained attention for its remarkable potential in food applications, particularly for proteins, as it induces structural modifications that directly affect their techno-functional properties **[1]** . Such modifications can be advantageous for the development of advanced food systems, including gels or 3D-printed foods, due to improvements in solubility and the formation of thermostable emulsions, for example. Previous studies have demonstrated that cashew nuts, obtained from a native tree of Brazilian biodiversity, can be used as a raw material for producing protein concentrates with excellent nutritional and sensory characteristics **[2],** however, some technological limitations remain. Therefore, the objective of this study was to evaluate the effects of CP processing on the techno-functional properties of cashew nut protein concentrates using Dielectric Barrier Discharge (DBD; 50, 500, and 1000 Hz) and Vacuum Plasma (10 and 30 min). Protein concentrates were produced by alkaline extraction followed by isoelectric precipitation, as described by **[2].** A protein concentrate without CP treatment was used as the control. All samples were subjected to techno-functional analyses, including solubility (pH 7.0), emulsifying capacity, emulsion stability, water and oil absorption capacities, and foaming properties, following the methods described in **[3]** . Protein content was determined according to **[4]** , color parameters were measured using the CIELAB system, and total color difference (ΔE) values were calculated. The results showed similar protein contents among samples, ranging from 67.5 to 71.5%. Notably, CP processing significantly improved the techno-functional properties of the protein concentrates. Vacuum Plasma treatment, particularly for 10 min, enhanced emulsion stability (114 min; control = 54 min) and solubility (57%; control = 49%), due to protein unfolding and the exposure of hydrophobic groups, which favor protein–water interactions and interfacial stabilization. In contrast, DBD treatments reduced solubility (44%, control = 49%) and emulsifying properties (for emulsifying capacity and emulsion stability, respectivelly: 21 m^2/g and 22 min for DBD, and control = 47 m^2/g and 54 min). CP application also induced color changes among samples; however, Vacuum Plasma treatments exhibited greater color stability compared to DBD treatments, with ΔE values ranging from 1.08 to 2.73. Overall, CP processing emerges as a promising non-thermal and environmentally friendly strategy to enhance the techno-functional properties of cashew nut protein concentrates, highlighting its potential for sustainable food processing applications.

Keywords:
Plant-based, Anacardium occidentale L., cold plasma.

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Acknowledgements:
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CASHEW APPLE FIBER AS A SUSTAINABLE INGREDIENT FOR NEXT-GENERATION PLANT-BASED FOODS

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The search for alternative sources of plant-based ingredients to improve the textural and sensory properties of plant-based meat alternatives is a growing trend, with strong potential to enhance the sustainability of global food systems. While research has primarily focused on plant-based proteins, it is well established that dietary fibers also play a key role in the textural and physicochemical properties of plant-based products **[1]** and therefore deserve greater consideration in product formulation. The cashew tree (*Anacardium occidentale* L.) is widely cultivated in tropical regions, particularly in Brazil, India, and several African countries. The cashew fruit consists of a nut and a peduncle (cashew apple), which together account for nearly 90% of the fruit and are commonly used for juice processing. After juice extraction, a residual bagasse is generated and is typically discarded. Previous studies **[2]** have demonstrated that this bagasse can be applied in meat analogues, mimicking the textural properties of meat products; however, appropriate treatment of the bagasse is required to improve its technological and sensorial characteristics. Therefore, this study aimed to develop economically viable technologies to transform fiber obtained from cashew apple bagasse, a byproduct of cashew processing, into a value-added ingredient for use in plant-based products. To this end, the effects of thermal treatment (80 or 90 °C), the number of sequential pressing extraction cycles (one or two), and drying methods (freeze-drying or oven-drying) were evaluated in terms of techno-functional, microbiological, physicochemical, chemical, microstructural, and sensory properties of cashew apple fibers. The results showed that thermal treatment at 80 °C was effective in producing fibers with low mold and yeast counts, which was consistent with microscopy observations (SEM and confocal analyses). Differences in chemical profiles, obtained by UPLC–PDA–ESI–QDA, were observed among treatments: freeze-drying resulted in higher levels of quercetin and myricetin, whereas oven-drying led to higher levels of anacardic acids, kaempferol, and luteolin. However, the different treatments did not cause significant changes in the volatile compound profiles identified by GC–MS. Regarding techno-functional properties, oven-drying induced structural modifications that negatively affected functionality, resulting in lower water absorption capacity (WAC) and oil absorption capacity (OAC) values. Sensory analysis revealed no significant differences between the number of pressing cycles for most sensory attributes; however, drying methods significantly influenced the sensory profile of cashew apple fibers. Freeze-dried fibers exhibited a lighter beige color, smaller fiber size, fewer dark spots, and improved chewability. When incorporated into a plant-based product (croquettes used as a test product, as described by **[2]**), sensory acceptance did not differ significantly among formulations for most evaluated attributes. Moreover, all croquette formulations showed high overall acceptance, with mean scores ranging from 7 to 8 on a 9-point hedonic scale, corresponding to “like moderately” and “like very much”. Finally, based on the overall results, a processing strategy prioritizing lower energy and water consumption was recommended, making it more economically and environmentally attractive. Consequently, fibers subjected to thermal treatment at 80 °C and one sequential pressing extraction cycle, whether freeze-dried or oven-dried, emerged as a promising and sustainable ingredient for plant-based products.

Keywords:
Anacardium occidentale L., cashew apple fiber, plant-based ingredients.

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Acknowledgements:

This research was funded by GFI (The Good Food Institute), the National Council of Technological and Scientific Development - CNPq (Ministry of Science, Technology and Innovation, Brazil, process n° 404293/2023-9 and 444421/2024-6), Funcap (FPD n° 0213-00247.01.01/23), Brazilian Agricultural Research Corporation - EMBRAPA (SEG process nº 20.24.00.204.00.00). A.P. Dionisio (process n° 304143/2025-1) and K.M.Canuto are CNPq Research Productivity Fellows.

Influence of chemical disordering of plant protein structure on emulsion stabilising properties: From an interfacial context

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Proteins are important functional ingredient owing to their emulsifying properties in many, if not most food products. In recent years, plant proteins are gaining interests over animal-derived dairy proteins due to the low environmental footprints of the former. Plant proteins do have hydrophobic and hydrophilic amino acids, which justify their ability to stabilise oil-in-water emulsions. However, plant proteins typically contain more β -sheets, fewer α -helices, and a higher proportion of fibrillar structures as compared to dairy proteins such as β -casein and such secondary structures in plant proteins often impede their emulsification behaviour. Therefore, in this study, we aim to investigate the effect of chemically disordering plant proteins and comparing their emulsification and interfacial properties with β -casein, an intrinsically disordered dairy protein, which is well-established as a classic emulsifier.
Plant proteins such as legumin from pea, patatin from potato and 11S globulin from sunflower seed were denatured using 8 M urea and dithiothreitol (DTT). Our results show that the addition of urea and DTT caused the interfacial tension of legumin, patatin, and sunflower 11S globulins to decrease rapidly, reaching values similar to that of β -casein (~18 mN/m). However, the droplet size measurements and confocal microscopy showed that the chemically disordered plant proteins showed broader size distribution of droplets (1 to 80 μm), unlike β -casein-stabilised emulsions showing smallest droplet sizes among the tested systems. Particularly, 11S sunflower seed globulin-stabilised emulsions exhibited largest droplet sizes, ranging from approximately 1 to 1,000 μm, and were highly aggregated. Interfacial shear rheological measurements showed that both patatin and legumin exhibited viscoelastic behavior, while 11S sunflower seed globulin formed a weak network at oil-water that was high susceptible to shear-induced deformation. Overall, this suggests that complete denaturation of secondary structure is not sufficient in some plant proteins to achieve interfacial behvaiour resembling dairy proteins.

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Acknowledgements:

This work was funded by the UK National Alternative Protein Innovation Centre (NAPIC), which is an Innovation and Knowledge Centre funded by the Biotechnology and Biological Sciences Research Council (BBSRC) and Innovate UK (Grant Ref: BB/Z516119/1).

Mapping formulation & process windows for fibrous plant based meat analogues

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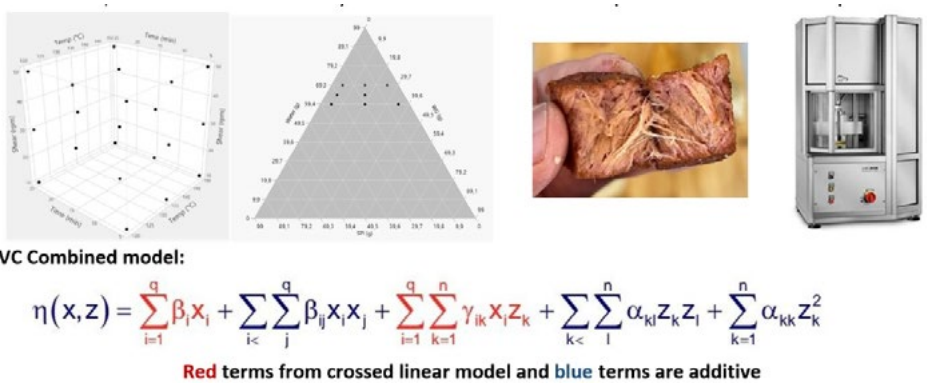
Creating convincing whole-cut **PBMAs** requires tuning both formulation and processing so that hot-state flow aligns protein domains and cooling fixes the structure without embrittlement [1]. Typical studies [2] vary only a few factors and therefore miss critical **mixture–process interactions** , producing isolated optima with limited transferability [3]. As a result, a formulation that performs well at one shear or temperature often fails when residence time, moisture distribution, or stress history shifts exactly the variability encountered when moving between equipment, scales, or product targets. This project uses an High temperature shear cell to generate reproducible thermal–shear histories [4] and a **mixture-by-process design of experiments** that jointly samples the formulation simplex and the process cube; responses will be analyzed with a statistical model [5]. This combined approach is designed to capture not only main effects but also crossed terms that reveal when a change in Soy Protein Isolate : Wheat Gluten : Water ratio alters sensitivity to temperature, shear rate, or residence time, enabling robust "windows" rather than single-point solutions. By fitting this model to data from **image-based fiber scores** , cutting mechanics, **orientation-resolved tensile properties** [6], and **oscillatory rheology with shear induced normal-force analysis** [7], the study will deliver contiguous, interpretable design-space maps that identify operable formulation–process windows and establish a foundation for mechanism-anchored descriptors (e.g., Young's modulus, fracture work, normal-stress coefficients) so recommendations become predictive rather than empirical. In addition, these maps will make trade-offs explicit (e.g., maximizing alignment vs. avoiding fracture) and support practical decision-making by linking microstructural anisotropy to mechanical performance and processability across the full mixture–process domain.



Mixture–process DoE and KVC model for HTSC. x: SPI (xi), WG (xj), Water (xk); z: residence time (zl), temperature (zm), shear rate (zn). Red=crossed x–z terms; blue=additive.

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Clean-label food preservation with pectin films incorporating rosemary oil-loaded solid lipid nanoparticles

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Consumers are more aware than ever about what they eat and the importance of environmental safety. Pectin, as a versatile plant-based hydrocolloid matrix, and essential oils, as natural preservatives, have garnered significant interest in addressing the growing demand for clean-label, sustainable, and eco-friendly food preservation. This project aims to investigate the potential of pectin films incorporating rosemary oil-loaded solid lipid nanoparticles (RO-SLN) in improving the quality and shelf life of ready-to-eat food products.
Pectin/RO-SLN films were characterized by their mechanical, thermal, morphological, and water barrier properties. The antibacterial and antioxidant potential of colloidal-based films was studied in ready-to-eat chicken breast to increase the food shelf life.
RO-SLN were successfully incorporated into the pectin matrix, without phase separation. RO-SLN improved the water vapor permeability of pectin films by about 90 %. SLN increased the bioactivity of RO in pectin films compared to unloaded RO. Pectin films containing RO-SLN had the highest antimicrobial and antioxidant activity, improved sensory attributes, and brought a two-day shelf life extension of ready-to-eat chicken breast to refrigeration conditions.
In conclusion, the proposed colloidal-based films represent a sustainable method of food packaging, having the potential to improve the quality and extend the shelf life of food products.

Keywords:
active packaging, water sorption, shelf life, bioactivity, nanocarrier

Acknowledgements:
This work was supported by the German Federal Environmental Foundation (Deutsche Bundesstiftung Umwelt, 30021/951-46 and 30025/064-46.

Thermal and Ionic Modulation of Pea Protein Isolate Nanoparticles (PPINs) Formation via pH-Shifting

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Pea protein isolate (PPI), a nutritionally balanced plant protein, exhibits limited solubility and conformational flexibility around neutral pH [1] . pH-shifting can induce controlled unfolding–refolding transitions to improve functionalities [2] . Thermal treatment and ionic strength are also known to modulate protein conformation and assembly [3] , yet their combined effects remain underexplored.

This study systematically investigated the effects of thermal treatment (25–90 °C) and ionic strength (0–200 mM NaCl) on PPINs fabricated through pH-shifting. Temperature was the predominant factor shaping particle characteristics: low-temperature conditions (25–50 °C) promoted non-covalent aggregation, yielding large, rough particles with high surface hydrophobicity, whereas high-temperature processing (70–90 °C) produced smaller, smoother, and more soluble nanoparticles with enhanced electrostatic repulsion and reduced surface hydrophobicity.

NaCl exhibited strong temperature-dependent effects. At temperatures ≤ 50 °C, increasing ionic strength decreased surface hydrophobicity and facilitated hydrophobic burial without altering disulfide bonds. At temperatures≥70 °C, on the other hand, NaCl triggered α-helix-to-β-sheet transitions, reduced disulfide bonding, lowered surface charge, and induced fluorescence quenching, indicative of enhanced tertiary compaction. Dissociation analysis further revealed distinct stabilization mechanisms: low-temperature PPINs were maintained mainly by hydrophobic interactions, while high-temperature PPINs relied on disulfide-bond networks that were progressively weakened by NaCl.

Keywords:
Pea protein isolate nanoparticles; pH-shifting; Thermal treatment; NaCl; Assembly mechanism

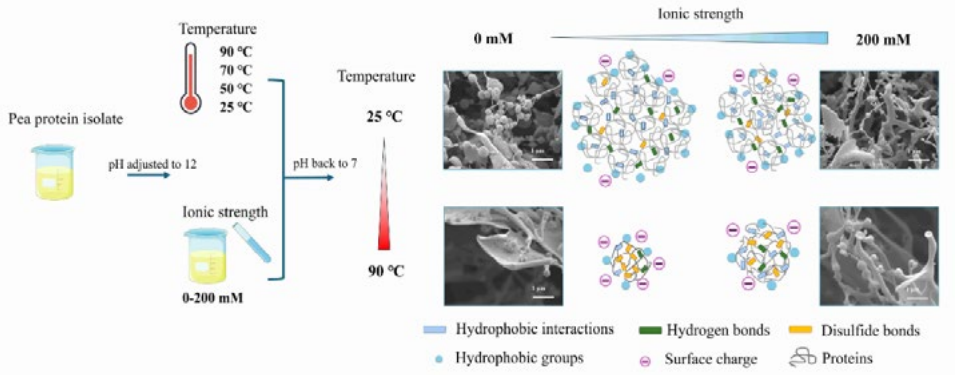

Fig. 1 Schematic illustration of the formation of PPINs induced by pH-shifting combined with thermal and ionic modulation.

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Acknowledgements:
The research was supported by the Chinese Scholarship Council.

pH-Shifting Combined with Thermal Treatment Modulates the Structural and Functional Properties of Pea Protein Isolate

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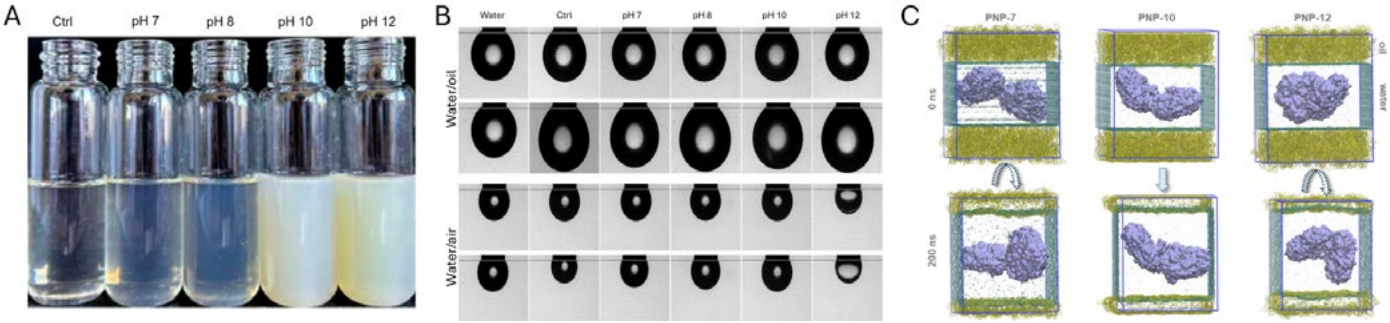
The practical applications of pea protein isolate (PPI) are often constrained by its limited solubility. This study systematically explores how pH-shifting combined with thermal treatment modulates the structural and functional properties of PPI through integrated experimental and simulation approaches. Alkaline exposure followed by neutralization induced pH-dependent conformational changes, revealing distinct mechanisms under different alkaline conditions. At pH 10, hydrophobic interactions predominated, resulting in increased turbidity and surface hydrophobicity, along with reduced foaming capacity due to excessive protein aggregation. In contrast, pH 12 treatment facilitated electrostatic stabilization and disulfide-mediated structural reorganization, producing smaller aggregates with improved colloidal stability but diminished foam persistence. The emulsifying properties were also markedly influenced by the pH conditions, exhibiting contrasting outcomes. Constant pH molecular dynamics (cpHMD) provided atomic-level insights into these transitions, confirming that pH 12 induced extensive tertiary structural rearrangement, whereas pH 10 favored hydrophobic-driven assembly. Importantly, pH-shifting under all conditions altered the PPI functionality primarily through changes in tertiary structure, while preserving the secondary structure as verified by circular dichroism and DSSP analyses, suggesting that the nutritional value may remain intact. The obtained results further underscored the critical role of protein–water hydrogen bonding in driving conformational changes during pH-shifting. Collectively, these findings establish pH-shifting as a versatile strategy to overcome functional limitations in PPI and present a novel framework for probing molecular-level structural dynamics during protein modification.

Keywords:
pea protein isolate, pH-shifting, cpHMD, colloidal stability, protein structure



A. Visual appearance of PPI dispersions. B. Snapshots of droplets formed by PPI aqueous dispersions in oil (top) and in air (bottom). C. Representative snapshots of PPIs obtained after 200 ns MD simulations in the oil–water interface.

Acknowledgements:
The research was supported by the Chinese Scholarship Council.

Synergistic effects of processing and stabilizers on the stability of fermented chili paste

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Fermented chili paste is a complex plant-based colloidal system that frequently suffers from phase separation and flavor instability during production and storage. In this study, the synergistic effects of mechanical processing and stabilizer addition on the stability of fermented chili paste were systematically investigated. Colloid milling at a chili-to-water ratio of 2:1 generated a more homogeneous paste with improved physical stability, as evidenced by reduced phase separation, enhanced viscoelasticity, and suppressed water mobility. Using this optimized base, the effects of xanthan gum, β-cyclodextrin, and rosemary extract were evaluated through a systematic formulation screening. The selected stabilizer combination markedly reduced centrifugal sedimentation and lipid oxidation while maintaining flavor integrity. Extended storage tests further confirmed that stabilized samples exhibited superior resistance to phase separation, color deterioration, and flavor degradation compared with untreated controls. GC-MS analysis revealed improved retention of key aroma compounds after prolonged storage. Overall, this work demonstrates that both processing-induced microstructural characteristics and stabilizer incorporation play critical and complementary roles in governing the stability of complex fermented chili paste systems, and provides practical formulation strategies for stable, high-quality fermented chili paste products.

Keywords:
fermented chili paste; mechanical processing; stabilizers; stability

Acknowledgements:
The author gratefully acknowledges the financial support from the China Scholarship Council (CSC).

Extraction, pH-Induced Modification, and Emulsifying Performance of Pea Globulin- and Pea Albumin-Enriched Fractions

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Pea protein is widely recognized as a sustainable plant-based protein with considerable potential for application in food emulsions. However, its utilization is often limited by poor solubility in aqueous systems, which adversely affects functional performance. On the other hand, pH-shifting has been shown to be an effective strategy to enhance the solubility and emulsifying capacity of pea proteins by inducing controlled structural modifications. Whereas globulins and albumins constitute the major protein components in peas, their individual responses to pH-shifting and their respective contributions to the emulsifying functionality remain insufficiently understood.

In this study, pea globulin-enriched fractions (PGEFs) and pea albumin-enriched fractions (PAEFs) were prepared using an alkali extraction–isoelectric precipitation (AE/IEP) method combined with a salt extraction procedure. The protein content was quantified, and the thermal denaturation behavior was evaluated to assess protein stability. The protein composition was characterized by sodium dodecyl sulfate–polyacrylamide gel electrophoresis (SDS-PAGE), with particular emphasis on the distribution of the major globulin subunits and albumin proteins. These analyses revealed clear differences in compositional profiles and thermal properties between PGEFs and PAEFs, reflecting their inherent structural differences.

Both protein fractions were subsequently subjected to pH-shifting modification involving exposure to extreme acidic or alkaline conditions followed by neutralization. Protein solubility was quantified across a wide pH range to evaluate the effect of this modification. Structural changes induced by pH-shifting were further investigated using circular dichroism (CD) spectroscopy to monitor alterations in secondary structure. SDS-PAGE analysis confirmed that the pH-shifting treatment did not result in extensive protein degradation, while pronounced conformational rearrangements were observed.

Keywords:
Pea Globulin, Pea Albumin, protein extraction, protein composition and conformation

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Acknowledgements:
The research was supported by the Chinese Scholarship Council

Wet-spun edible scaffolds with muscle-like fiber alignment: colloidal microstructure control and myogenic biofunctionality for cultured meat

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Edible scaffolds with controlled microstructure and biofunctionality are critical for emerging food structuring technologies, including cultured meat and advanced protein foods. In this study, we developed and comparatively evaluated xanthan gum composite scaffolds incorporated with seaweed powders as multifunctional food-grade colloidal systems. Xanthan gum contributed shear-thinning behavior and processability. Seaweed powders were incorporated (0–2%, w/w) to introduce charged polysaccharides, antioxidant activity, and mineral-rich bioactivity.
Scaffolds were fabricated via wet-spinning, producing aligned fibrous structures resembling muscle-like architectures. The effects of seaweed type on scaffold morphology, water absorption, molecular interactions, and functional performance were systematically characterized using SEM, FTIR, and swelling analyses. The incorporation of different seaweed species resulted in distinct colloidal behaviors and scaffold properties, reflecting differences in polysaccharide composition.
Cell-based assays further demonstrated that all scaffolds supported cell attachment, proliferation, and viability over seven days, with seaweed-specific differences in myogenic differentiation potential. Overall, this work highlights how seaweed-derived colloidal components can be strategically integrated into protein–polysaccharide scaffolds to modulate structure, functionality, and bioactivity. These findings provide a sustainable and food-safe design framework for next-generation edible scaffolds and structured food systems.

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Acknowledgements:

This study was supported by Korea Evaluation Institute of Industrial Technology [KEIT] (Project name: 3rd stage of industrialization and establishment of cultured meat production base technology, Project number: 20012411)

Seed Oleosomes: Nature's Design for Dispersible and Stable Emulsions

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Seed oil reserves, which can constitute over half of an oilseed's volume, are packaged as oleosomes that disperse upon hydration to form stable emulsions. Their inherent interfacial architecture of oleosomes combines a triglyceride core with a phospholipid monolayer and structural proteins, providing intrinsic colloidal stability without chemical additives. We aspire to translate the inherent functionality of oleosomes into practical technologies for clean-label food systems, cosmetic formulations, and industrial products.

This research evaluates aqueous processing approaches for isolating oleosomes from whole canola seeds and anatomically separated hull and kernel fractions of the *InVigor L340PC* variety, enabling fraction-specific characterization. Dehulling was achieved using dry ice milling followed by aspiration. Oleosomes were obtained through soaking, blending, filtration, and centrifugation, with sequential aqueous extraction applied to improve recovery and reduce the co-extraction of undesirable components.

Sequential aqueous extraction effectively reduced sinapine, a bitter phenolic compound, by 94% after a single extraction and by 99.9% following three successive extractions, demonstrating the potential for aqueous processing to produce an oleosome dispersion suitable for food applications. Hull-derived oleosomes exhibited a markedly elevated proportion (>20%) of a rare fatty acid, asclepic acid, contrasting with the typically low levels in whole seed or kernel oleosomes (up to 5.8%). This enrichment of asclepic acid highlights the role of seed fractionation in tailoring oleosome lipid composition.

Compositional and structural characteristics of the oleosomes obtained were examined using proton and carbon-13 nuclear magnetic resonance (^{1}H and ^{13}C NMR), scanning electron microscopy (SEM), confocal laser scanning microscopy (CLSM), and particle size distribution analysis. SEM performed on freeze-dried aqueous samples revealed fraction-dependent differences, with kernel-derived samples forming compact, spherical lipid–protein aggregates, whereas hull-derived samples exhibited more heterogeneous and fibrous structures. Particle size analysis supported these observations, with kernel oleosomes displaying narrower size distributions compared to hull and whole-seed fractions.

This work shows that aqueous extraction can access nature's prefabricated oil bodies as a concentrated, dispersible lipid resource. By retaining the native protein–phospholipid interface, these emulsions achieve stability and functionality with fewer inputs than induced systems, advancing sustainable, clean-label product design.

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Acknowledgements:
Agricultural Development Fund: 20220097
Saskatchewan Structural Sciences Centre
Government of Saskatchewan
College of Agriculture and Bioresources, Usask

The pH shifting effect in the structuring of hybrid gels formed by pea protein and casein micelles

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Due to growing concerns about the sustainability and environmental impact of the food industry, there is a need to shift from systems formulated with animal proteins to plant-based proteins, as they require less land and water and are associated with lower CO_2 emissions [1]. The complete transition from animal proteins to plant-based proteins remains difficult, as consumers face barriers associated with the flavor characteristics of the plant-protein products. Thus, an easy way to stimulate this transition is through the creation of a hybrid system, which reduces animal protein consumption while mitigating the off-flavors associated with plant-based proteins [2]. When combined in the same system, proteins from different sources, such as casein micelles and pea protein, tend to form independent structures, which is undesirable from the perspective of food product formulation [3]. A way to improve this type of interaction is by modifying protein structure, for example, by applying pH shifting. The pH-shifting technique consists of adjusting the pH to extreme acidic or basic conditions and subsequently returning it to neutral pH. This process induces the formation of "molten globules", which are intermediate conformational states during protein unfolding that retain the secondary structure of the native state [4]. Thus, this work aims to evaluate the effect of pH shifting on the modification of pea protein and its subsequent effect on hybrid gels formed with casein micelles. First, pea protein (12% w/w) was submitted to a pH shift to pH 12 and maintained under agitation for 12 hours. After this, the suspension pH was neutralized to pH 7. The suspension was analyzed, and hybrid gels with casein micelles in different ratios (casein/pea—80:20, 50:50, 20:80) were then formulated, and their structure was analyzed by Texture Profile Analysis (TPA). Modified pea protein showed increased solubility, reduced particle size, higher zeta potential, and decreased intrinsic fluorescence intensity, indicating conformational changes and exposure of buried tryptophan residues. These structural changes influenced gel behavior depending on the protein ratio. Gels with higher pea content showed increased hardness and water-holding capacity, while in casein-rich gels, hardness decreased, likely due to altered protein–protein interactions. The results highlight the potential of pH shifting in modifying pea protein and enhancing interactions between pea and casein in hybrid systems, making it a viable option for food industries seeking to formulate hybrid gels.

Keywords:
Sustainable systems, Hybrid gels, Pea proteins, Casein micelles

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Acknowledgements:
We gratefully acknowledge the Brazilian funding agencies CNPq, Fapemig, and the Coordenaçãoo de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES)—Finance Code 001, for the financial support.

Emulsifying and antioxidant properties of protein fractions derived from nut and oilseed co-products: State of the art and perspectives

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Emulsions are prominently present in our daily foods, and are thus currently affected by the plant protein transition. It is therefore essential to identify plant-based emulsifiers which can efficiently guaranty the physical stability of emulsions. Plant-based proteins ingredients have been extensively studied for this purpose, in particular isolates derived from pulses such as pea or faba bean seeds, owing to their high protein content. Oil-rich seeds such as canola, sunflower and soy also contain a significant protein content. Although primarily used for oil production in harsh conditions (high temperature, solvents), the resulting pressed cakes may be processed into food-grade protein isolates. This is a higher-value valorisation of these co-products compared to animal feed, but it requires extensive purification steps. An alternative approach could be to deploy milder fractionation processes to obtain protein concentrates (usually 50 - 70 wt.% protein) instead of isolates (> 70 wt.% protein), which could be a means to preserve other endogenous components of the pressed cakes. For instance, PUFA-rich oilseeds and nut kernels contain a rich diversity of bioactive lipophilic molecules, such as antioxidants. In this way, multifunctional ingredients could be obtained, which could not only physically stabilize emulsions, but also prevent oxidation phenomena. This is a good illustration of the current trend questioning the relevance of protein purity as the main, or even the only indicator of the quality of protein ingredients.
In this context, we aimed at reviewing the current data available on protein fractions obtained by mild fractionation of PUFA-rich oilseed and nut kernel pressed cakes, with a focus on their protein composition as well as non-protein constituents. This could be useful to get a better understanding of their emulsifying and antioxidant properties, thereby contributing to expanding and rationalizing the plant protein portfolio for food applications.

Keywords:
food emulsions, plant-based emulsifiers, nut and oilseed co-products, endogenous lipids

PLANT-BASED COATINGS TO ENHANCE THE BARRIER PROPERTIES OF KRAFT PAPER FOR FOOD PACKAGING APPLICATIONS

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Coating with bio-based polymers applied to the paper surface can be a viable and environmentally friendly alternative to petroleum-based polymers for packaging applications [1]. This study explores the potential application of emulsions containing naturally sourced and non-animal polysaccharides (P), proteins (PP1 and PP2) and waxes (W1, W2 and W3) as a bio-based coating materials on the surface of kraft paper (40 g/m ^{2}) at pilot-scale for food contact packaging. Rheological behaviour of the developed coating formulations was analysed to verify the potential of the formulations for industrial-scale application. Following this, the air and water vapor permeability, grease resistance, and mechanical properties of the coated kraft paper were evaluated to determine its barrier performance . Two optimized coatings exhibited a grease kit value of 8/12, in contrast to 0/12 for the uncoated paper, while the oil Cobb value demonstrated an improvement of approximate 90% (lower than 2 g/cm ^{3}). The minimum air permeability of the coated paper reached over 1620 s/100 ml, as determined by the Gurley test. Water vapor permeability was significantly reduced, whereas mechanical barrier properties (including bursting strength, tearing resistance, tensile strength, elongation at break, and Young's *modulu* s) were enhanced. Overall, the two studied formulations P-PP1-PP2-W1-W2 and P-PP1-PP2-W3 based emulsion yielded promising evidence for sustainable packaging development.

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Acknowledgements:

This work was financed by the "From fossil to forest" project supported by Plano de Recuperação e Resiliência; IAPMEI - Agência para a Competitividade e Inovação. IP. This study was also supported by the Portuguese Foundation for Science and Technology (FCT) under the scope of the strategic funding of UIDB/04469/2020 unit. and by LABBELS – Associate Laboratory in Biotechnology. Bioengineering and Microelectromechanical Systems. LA/P/0029/2020. and under the scope of the strat egic funding of UIDB/04469/2020

Role of different proteins on the melting properties of high protein plant-based cheese

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As plant-based products gain popularity, many analogues of animal-based foods are being developed, plant-based cheese is one of these products. The functional properties of plant-based cheese should replicate those of their dairy versions, but the nutritional content and melting properties of current commercial products are unsatisfactory. The commercial cheese analogues are mainly made of native starch, which forms a non-thermoreversible particle gel network. Our previous research proved that oxidized starch can form a polymer gel network which fully collapse after heating, the melting behaviour of which can be controlled by adding protein. Additionally, the micro-structure of the starch-protein network was shown to depend largely on the water distribution within the system. However, limited knowledge is available on how to increase protein content and reduce starch to a minimal level an still be able to control said properties. Therefore, the aim of this study was to investigate how plant proteins affect the melting properties of starch-protein system, and to find the link between water distribution, micro-structure and melting properties. In our study, different plant proteins (pea, soy, potato) and their aggregates were added to a oxidized starch gel system at different concentrations (10,15,20%). Potato protein showed the lowest degree of meltability according to Schreiber test. The effect of different protein sources can be explained by the theoretical water balance (TWB) of the protein-starch gels. Higher water holding capacity (WHC) of protein results in a greater water shortage in the protein-starch system, which leads to limited water availability for the starch, resulting in a denser polymer network and more resistance to melting. Confocal laser scanning microscopy (CLSM) images further proved that potato protein retained more water in the protein-starch system than others. To alter the functionality of proteins, potato and soy proteins are heated and freeze dried to make protein aggregates. The decreased water holding capacity of protein aggregates resulted in a lower water shortage of starch-protein gel system, potato protein aggregates- starch gel achieved limited melting behaviour at 20% protein concentration. These findings will give us insights on how to design protein characteristics for modulating the melting properties of protein-starch gels.

How high molecular mass dextrans from Weissella cibaria affect milk gel properties

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Commercial thickeners are widely used in food formulae to enhance functionalities that are mainly attributed to high water-binding capacity, but only a few of these are polysaccharides of microbial origin. Major drawbacks are the high costs or missing QPS/GRAS status of the production organism, or in the case of *in situ* production during food fermentation, the low polysaccharide amount. There are, however, some promising strains from the genus *Weissella* with pending safety assessment, which produce high amounts (> 1 g/L) of high-molecular mass dextrans (> 10^6 Da). For predicting their functionality, the intrinsic viscosity [η] can be used, which generally increases with molecular mass (Mark-Houwink equation). The aim of this study was to investigate the structural and macromolecular properties of these high-molecular mass dextrans and to estimate their techno-functional potential.
Dextran from *W. cibaria* DSM14295 produced in a 3.6 L bioreactor was isolated from the fermented medium and freeze-dried to obtain a powder [1]. A commercial dextran from *Leuconostoc mesenteroides* was used for comparison. The structures of both samples were confirmed as dextrans with a backbone of 1,6-linked glucopyranoses and ramifications at position *O* 3 (approx. 3 – 4 %). Molecular mass and thus [η] were higher for *Weissella* dextran than for the commercial dextran ($2.2{\cdot}10^9$ and $2.3{\cdot}10^5$ Da; 52 and 44 mL/g, respectively). To evaluate their effects on model milk gels, the dextrans were added to milk prior to acidification with glucono-δ-lactone, and gelation was recorded using thromboelastometry (small sample amounts) and rheometry. Gel stiffness increased linearly with dextran concentration, independent from the gelation recording method. For *Weissella* dextran, however, gel stiffness declined again at a certain concentration level probably due to the steric hindrance of molecules with higher molecular mass and hydrodynamic radius (263 vs. 12 nm). The disturbance of the formation of a homogenous protein network is reflected in weaker milk gels as well as larger serum pores and thicker protein strains in images from confocal laser scanning microscopy. Syneresis was not affected by this phenomenon: Forced syneresis decreased with higher *Weissella* and commercial dextran concentrations from 49 % to 19 and 39 %, respectively.
Our experiments showed that high molecular mass dextrans from *W. cibaria* can be produced in high amounts and were able to improve milk gel properties.

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This work has been supported by Deutsche Forschungsgemeinschaft (DFG), project IDs: JA2033/3-1 | WE6416/4-1.

From leaf to texturing agent: Functional polysaccharides from Corchorus olitorius L.

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Polysaccharides (PS) from plant sources are widely used as hydrocolloids due to their ability to modulate the rheological and textural properties of food systems. In the context of diversifying sustainable and underutilized sources of functional polysaccharides, *Corchorus olitorius* (mloukhia) leaves represent a promising candidate, as they are rich in mucilage polysaccharides with potential thickening properties [1]. Its polysaccharides improved food texture, as demonstrated in yogurt formulations [2] and through synergistic effects with carrageenan gels in relation to gel strength [3].
In this study, PS were extracted from Tunisian *C. olitorius* leaves using pH-adjusted water, and the extraction process was optimized using response surface methodology based on a Box–Behnken experimental design. The effects of extraction temperature (70-100 °C), extraction time (60-180 min), and solution pH (4-6) on extraction yield, purity, and rheological properties were investigated. The optimal extraction conditions were determined to be 70 °C, 3 h, and pH 4.
The rheological behavior of aqueous PS solutions was characterized using shear and oscillatory measurements. The PS solutions exhibited a pronounced pseudoplastic behavior and showed a critical concentration of 2.01 % (w/w) for the formation of a weak gel network. At low concentration (0.1 % w/w) and low shear rates, *C. olitorius* PS solutions displayed higher apparent viscosity than sodium alginate and guar gum under comparable conditions. Moreover, a clear synergistic gelling effect was observed when *C. olitorius* PS were combined with κ-carrageenan, resulting in enhanced gel strength.
These results highlight the strong texturizing potential of *C. olitorius* leaf polysaccharides and support their relevance as a sustainable plant-based hydrocolloid for food and related applications.

Keywords:
Corchorus olitorius L., polysaccharides, extraction, optimization, texturing agent, rheology

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Acknowledgements:
This research was funded by a CIFRE grant (n°2023/1679) awarded by the ANRT to SELT FRANCE BIOTECH SAS, in support of the work of Emma Bonnot, PhD student.

Isolation of β-glucan and chitin-glucan complex from cell walls of fungal biomass and waste stream by sequential extraction

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This study investigated how sequential extractions affect carbohydrate recovery from isolated cell wall fractions (CW) of fungal *Paecilomyces variotii* biomass (P.V.) and waste from commercial fungal *Hericium erinaceus* extract production (H.E.). After cell wall isolation, the mass yields were 25-28% for CW_P.V. and > 95% for CW_H.E. Alkaline extraction of CW produced a soluble β-glucan fraction (Sol-BG) and insoluble fraction, which was further acid-extracted aiming for separation of soluble chitosan fraction and chitin-glucan complex fraction (CGC). Fractions were characterized by monosaccharide and total sugar analysis, elemental analysis and FTIR. CW_P.V . contained 48% total sugar while CW_H.E. contained 55% total sugar. The mass yields (relative to CW) of Sol-BG_P.V. and CGC_P.V. were at 41% and 28%, respectively. Unexpectedly, Sol-BG_P.V. contained only 19% total sugar whereas CGC_P.V. consisted entirely of sugar. Compared to P.V. extraction, mass yields of H.E. in Sol-BG and CGC fractions were lower, i.e. 16% and 21%, respectively. Total sugar contents of Sol-BG_ H.E. and CGC_ H.E. were 53% and 83%. Since no chitosan was recovered by tested conditions, chitin was only concentrated in CGC fractions. For developing an effective fungal biomass extraction strategy, further work is needed to optimize the extraction process and to assess functionality of the fractions.

Keywords:
Chitin-glucan complex, β-glucan , fungal biomass, cell wall, isolation

Acknowledgements:
This study was supported by Business Finland under Grant ID 1524/31/2024.

Effect of Quince (Cydonia oblonga) Seed Mucilage-Based Bioactive Coating Loaded with Thyme (Thymus vulgaris) Essential Oil on the Physicochemical, Microbiological, and Sensory Quality of Refrigerated Turkey Breast Fillets

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Today, a growing focus among researchers and the agro-food industry on sustainability and environmental issues has encouraged the investigation and valorization of agricultural by-products for the development of natural and eco-friendly materials. These approaches not only minimize the ecological footprint but also contribute to the circular economy by converting waste into value-added products. In this context, seeds obtained from quince fruit (*Cydonia oblonga*), typically regarded as industrial waste, represent a promising source of valuable biopolymers and offer potential as a natural source of mucilage with functional properties suitable for food applications. The transformation of a by-product from one production step into a value-added resource for another may further promote sustainable practices and minimize waste generation. Therefore, this study aimed to utilize mucilage derived from quince seeds as a natural coating material, formulate a thyme essential oil (THO)-incorporated quince seed mucilage (QuM) bioactive edible coating, and evaluate its effect on the quality characteristics of turkey breast fillets (TBF) during refrigerated storage. QuM-based bioactive edible coatings containing THO at different ratios (0–2%) were applied to TBF samples, and both untreated (control) and coated fillets were analyzed for physicochemical properties (pH, oxidative stability, color, and hardness), microbiological quality (total viable count and total coliform count), and sensory attributes (appearance, texture, taste, and general acceptability) over a storage period of 10 days at 4 °C. During cold storage, significant increases in pH, lipid oxidation indices (peroxide value and TBARS), b* value, total color difference, and microbial counts were observed in TBF samples, while hardness, L*, and a* values showed a marked decrease over time. The application of QuM-based coatings containing higher concentrations of THO, particularly at 1.5% and 2%, effectively reduced these deteriorative changes and contributed to improved preservation of physicochemical properties, enhanced microbial quality, and better sensory attributes, including appearance, texture, and taste of cooked fillets, as well as overall acceptability of fresh fillets, compared to the control samples. In conclusion, THO-enriched QuM-based bioactive edible coatings effectively maintained the quality of turkey breast fillets by inhibiting microbial growth, stabilizing pH and color, preserving texture, limiting lipid oxidation, and enhancing sensory properties during refrigerated storage for 10 days at 4 °C.

Keywords:
Seed mucilage, valorization, bioactive coating, fresh meat, thyme essential oil

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Acknowledgements:
The authors thank the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No. 952594 (ERA Chair project DRIFT-FOOD).
The authors are thankful to Pınar Meat Company for providing the turkey meat used in this study.

Green Extraction and Functional Properties of Insect Proteins from Black Soldier Fly Larvae and Yellow Mealworm Using SC-CO_2, Ultrasound, and Pulsed Electric Field.

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Edible insects are promising alternative protein sources, but scalable and sustainable processing strategies are needed to obtain high-quality, functional protein ingredients. This study investigates a green processing concept for protein enrichment from black soldier fly larvae (BSFL) and yellow mealworm using supercritical CO_2 (SC-CO_2) defatting combined with emerging physical extraction technologies, namely high-intensity ultrasound (HIUS) and pulsed electric fields (PEF). The approach aims to improve protein concentration while preserving structural integrity and techno-functional properties. SC-CO_2 defatting of BSFL reduced oil content from 16.68% to 2.82%. Protein structure was preserved after processing, as indicated by FTIR and SDS-PAGE, showing similar secondary structure and molecular weight distribution compared to untreated samples. HIUS and PEF pre-treatments were evaluated under mild aqueous conditions. HIUS provided moderate increases in extracted protein content, while PEF showed limited effect within the tested parameter ranges, and statistical modelling indicated no significant parameter effects under neutral extraction conditions. Selective recovery of more soluble, low-molecular-weight protein fractions was observed. Yellow mealworm processed with the same concept showed oil reduction from 27.52% to 4.41% after SC-CO_2 defatting. The extracted lipid fraction was rich in palmitic (18%), oleic (30%), and linoleic acid (40%). Protein concentration for yellow mealworm increased from 31% to 38–39% after PEF and to 34% after HIUS, indicating selective enrichment potential. To support food application, extracted proteins will be evaluated in low-fat oil-in-water emulsions (5% oil), where emulsion capacity and emulsion stability will be measured according to established protein functionality assessment approaches. The integrated mild-processing strategy of SC-CO_2 combined with HIUS and PEF supports development of structurally preserved and techno-functional insect protein ingredients for sustainable food systems.

Keywords:
Keywords: insect protein, supercritical CO_2, ultrasound, pulsed electric field, emulsifying properties, sustainable processing

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Sustainable Cascading Extraction of Functional and Nutritional Compounds from Shore Crab (Carcinus maenas) Side-streams

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The European shore crab (*Carcinus maenas*) has increased markedly in Danish coastal waters, contributing to ecological imbalance through predation pressure on native species. At the same time, this species represents an underutilized marine bioresource with strong potential for high-value ingredient production. CRABEX addresses this dual challenge by developing a sustainable cascading biorefinery concept for full valorization of shore crab side streams, aiming to recover proteins and peptides, minerals, chitin/chitosan, and astaxanthin-rich lipid fractions for applications in aquafeed, food systems, and potentially health-oriented products. Crab shells contain substantial levels of structural biopolymers and nutrients, particularly chitin and proteins, as well as minor but valuable carotenoids such as astaxanthin. The project optimizes an integrated extraction pathway combining supercritical fluid CO_2 (SC-CO_2), enzyme-assisted extraction supported by ultrasound, and targeted conversion steps to generate functional and nutritionally characterized protein ingredients, alongside bioactive chitosan. SC-CO_2 will be applied as an initial step to extract lipids, potentially enriched in carotenoids, based on previous literature from crustacean by-products (Ahmadkelayeh & Hawboldt, 2020; Félix-Valenzuela et al., 2021). Following defatting, proteins will be released through enzymatic processing, supported by ultrasound to enhance mass transfer, and the resulting proteins and hydrolysates will be evaluated for amino acid composition, protein profile, and molecular weight distribution. Their incorporation in feed and foodsystems as well as potential bioactivity will be assessed. Similar approaches have shown promising functionality of recovered proteins from *C. maenas* and other crab side streams (Kang et al., 2020). Finally, chitin will be isolated from the remaining shell matrix and converted into chitosan, which will be assessed for bioactivity and functionality (Aranaz et al., 2021). Through this integrated approach, CRABEX seeks to enable sustainable valorization of shore crab side streams by converting an abundant marine waste resource into scalable, high-value nutritional and functional ingredients, while strengthening the economic viability of more sustainable processing pathways.

Keywords:
Sustainable extraction, chitin, protein hydrolysate, food and feed ingredient, crab shell

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Acknowledgements:
We gratefully acknowledge the GUDP Foundation, DK, for providing the financial support that enabled the realization of this project.

Valorisation of marine side-streams and jellyfish into functional ingredients

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Underutilised marine resources such as jellyfish and side-streams from seafood processing represent promising sources of functional proteins that can support the transition toward a more sustainable and circular bioeconomy. Within the FOODIMAR project, we investigated approaches to extract, purify, and characterise collagen- and gelatine-rich fractions from fish side-streams (i.e. skin, head- and backbones) and moon jellyfish (*Aurelia aurita*). The resulting extracts were evaluated for key colloidal functionalities including emulsification, foaming, and gelation. Both collagen and gelatine extracts exhibited promising techno-functional properties compatible with colloidal food applications. For moon jellyfish specifically, electrodialysis was explored to reduce their natural high salt content (approximately 75% on a dry matter basis), thereby improving both their nutritional and functional potential. In parallel, spray drying of moon jellyfish was assessed as a means of producing stable powder ingredients suitable for incorporation into food systems. Overall, this work highlights how marine by-products and jellyfish can be converted into functional protein ingredients contributing to a more sustainable food industry.

Keywords:
Marine side-streams, jellyfish, collagen, gelatine, functional proteins

Acknowledgements:
This work has received funding from the EU project “FOODIMAR” under the first call of the Sustainable Blue Economy Partnership 2023 – “The Way forward: a thriving sustainable blue economy for a brighter future”.

Physicochemical and Rheological Properties of a Soy Yogurt-like Product Fermented by Yogurt Bacteria Co-cultured with Exopolysaccharide Producing Lactic Acid Bacteria and Yeast

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Introduction

Plant-based yogurts are gaining popularity, yet achieving a dairy-like texture and stability is difficult because plant proteins form weak gels, which lead to syneresis and often require additives. Using exopolysaccharide (EPS)–producing lactic acid bacteria (LAB) as starter cultures may offer a natural solution, as EPS act as natural thickeners and stabilizers, enhance gelation and water-binding capacity [4] . Previous studies show that co-culturing EPS-producing LAB with yeast can enhance EPS production [1], [2] , hence influencing yogurt rheology [3] . This study investigates how co-culturing EPS-producing LAB with yeast influences EPS production and the rheological properties of a soy-based yogurt-like product.

Methods

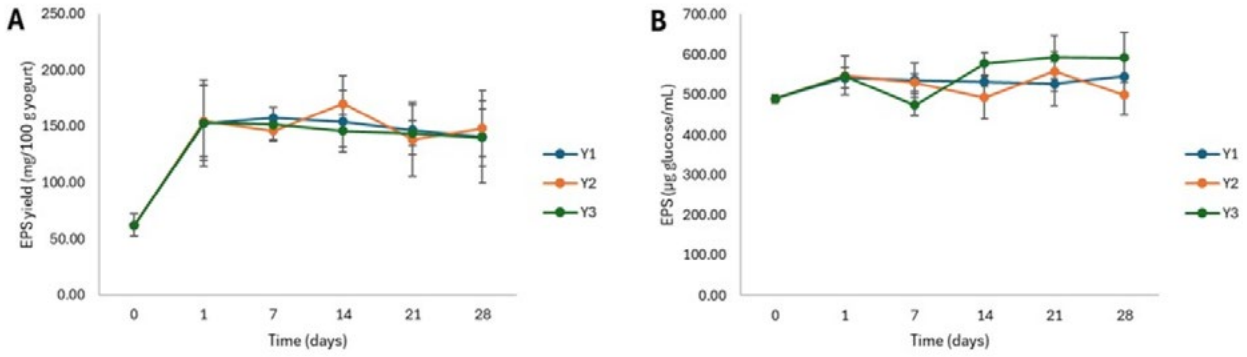
Three soy yogurt–like products were prepared: Y1 (control with traditional starter cultures *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*), Y2 (Y1 starter cultures + EPS-producing LAB), and Y3 (Y2 starter cultures + yeast). Sucrose served as the carbon source. The EPS-producing strain was *Lactobacillus kefiranofaciens* OSU BDGOA1, used either in mono- or co-culture with the yeast *Kluyveromyces marxianus* BDGO YM6. The EPS production of the yogurts was quantified every seven days for 28 days of storage at 4°C after fermentation alongside with evaluation of the rheological and physicochemical properties of the products. The rheological data were fitted to a power-law model to determine the power-law constants for comparison across treatments.

Results

Bacterial EPS was produced in all fermented treatments and the yield was higher than in the unfermented soymilk (day 0). The EPS measured in the unfermented soy milk is attributable to the gellan gum present in the commercial soymilk base. Flow index (n) and consistency index (k), describing apparent viscosity, did not differ significantly across treatments. During storage at 4°C, the flow index decreased and the consistency index increased within each treatment. Storage modulus (G′) remained higher than loss modulus (G″), indicating solid-like behavior. Power law constants and frequency indices did not differ across treatments, but G′ and G″ power law constants increased significantly within each treatment over storage. EPS levels in mono- and co-cultured yogurts matched the control, explaining the unchanged rheology. Y3 showed higher pH and lower acidity during storage due to yeast metabolism. Water holding capacity was similar across treatments but decreased during storage.

Conclusions

This study shows that co-culturing *L. kefiranofaciens* with *K. marxianus* does not enhance EPS production or improve the rheological properties of the soy yogurt produced compared to other studies with cow's milk. However, the co-culture altered pH and acidity during storage, indicating that yeast–LAB interactions may influence flavor development rather than texture for this scenario.



(A) EPS yield expressed as mg/100 g yogurt. (B) EPS concentration expressed as µg glucose/mL. Values represent mean ± SD.

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Optimization and scaling of protein concentrate from defatted almond cake for the development of protein-enriched plant-based foods.

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The growing global demand for plant-based proteins and the necessity to implement circular economy models have propelled the search for sustainable alternative sources. Agro-industrial byproducts, frequently underutilized, represent valuable feedstock for obtaining high added-value ingredients. In this context, the present study focused on the valorization of defatted almond cake, a residue from the oil extraction industry with an initial protein content of 47.4%.
The primary objective was to obtain a protein isolate through the optimization of alkaline-acid extraction. An experimental design was employed to evaluate the effect of six key parameters: pH, salt concentration (NaCl), temperature, agitation speed, solid-to-liquid ratio, and extraction time. Statistical analysis revealed that the interaction between pH and salt concentration was highly significant, indicating that salt addition negatively impacts yield in alkaline media. Furthermore, the quadratic terms for temperature and time were found to be significant, suggesting critical non-linear behaviors, whereas the linear effects of temperature, agitation, time, and ratio were not significant for response maximization within the studied ranges.
Optimal extraction conditions were established at a pH of 10.4 with no salt addition, an ambient temperature of 23.8 °C, moderate agitation at 244 rpm, a solid-to-liquid ratio of 1:15.3 (w/v), and a residence time of 1 hour. Subsequently, a solubility curve was constructed, identifying pH 4.5 as the optimal isoelectric point for protein precipitation.
Under these validated conditions, a final product with a protein purity of 77.8% was achieved. The process was successfully scaled up to a pilot plant level, where the resulting ingredient exhibited relevant techno-functional properties, specifically an oil absorption capacity of 80% and an emulsifying capacity of 54%, demonstrating its suitability for the formulation of plant-protein-enriched foods.

Keywords:
Almond protein isolate, protein extraction, techno-functional properties, byproduct valorization, pilot plant scale-up.

Acknowledgements:
This work was supported by the project PROSOST. AT22CCTT_00007, funded by the Junta de Andalucía through the Ministry of University, Research and Innovation, and co-financed by the European Regional Development Fund (ERDF, 80%) under the Andalusian ERDF Operational Programme 2014–2020.

Lipopeptides in Food Systems: An Underexplored Frontier in Food Colloid Science

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Peptides are well established and extensively investigated as functional ingredients in food systems, with consolidated knowledge on their structure-function relationships and interfacial behavior. Lipopeptides, on the other hand, are only recognized in microbiology and biomedical research for their antimicrobial properties and self-assembly ability [1], while their surface activity potential remains comparatively underexplored within food science.
The presence of both a peptide backbone and a lipid moiety confers intrinsic amphiphilicity to lipopeptides, making them promising candidates for foams and emulsions stabilization. Despite these well-known functional attributes, systematic studies addressing their behavior in complex food colloids, structure-function relationships under processing conditions, and techno-functional performance are still unexplored.
This work provides a critical overview of the current knowledge on lipopeptides, highlighting key research gaps, and aims to stimulate further investigation into the rational exploitation of lipopeptides in food systems.

Keywords:
Lipopeptides, Surfactants, Emulsions

References:

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The impact of high vs. low methoxyl pectin on the macroscopic phase stability of oat protein isolate

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The shift to sustainable, plant-based food systems needs to address the poor stability of plant proteins in liquid form. Oat protein isolate (OPI) has potential for nutritional and environmental sustainability. However, OPI aggregates near its isoelectric point (pI ~5.3). Mixing proteins with polysaccharides is a common way to improve stability, but it's still unclear if the stabilization models developed for dairy or soy can be applied to oats.
We have studied the stabilization of OPI using high methoxyl pectin (HM-pectin) and low methoxyl pectin (LM-pectin). Design of experiments (DoE) was used to assess the impact of pH (from 3 to 7), protein concentration, and pectin concentration on overall stability. Stability was evaluated through macroscopic phase stability, dynamic light scattering, rheology, and zeta potential, with support from multivariate factor analysis.
Our results show that HM-pectin and LM-pectin increased the macroscopic phase stability, defined as the retention of more than 90 % of the total protein within a single, continuous phase, under different formulation parameters. HM-pectin prevents phase separation mainly in acidic conditions, at pH levels of 5.3 or lower. HM-pectin works effectively at lower pectin-to-protein ratios. However, as the pH rises above the isoelectric point, HM-pectin 's ability to stabilize the OPI is reduced, necessitating higher pectin concentrations to keep a large protein phase and prevent precipitation. On the other hand, adding LM-pectin creates a wider range of macroscopic stability across the range of pH, as long as a minimum of pectin concentration (~1 wt%) is reached. LM-pectin forms stable systems both below and above the protein's isoelectric point. Multivariate factor analysis suggests that LM-pectin stabilization relies less on surface interactions and is more connected to creating a thick, electronegative network that limits phase separation. Notably, for both types of pectin, stabilization was not correlated with a low particle size.

Keywords:
Oat protein, colloidal stability, high methoxyl pectin, low methoxyl pectin, plant-based, phase separation

Valorization of lentil aquafaba and flour for the development of sustainable bioplastics via injection molding

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Plant proteins have emerged as a promising source for biodegradable materials to address the urgent need for alternatives to non-renewable, petroleum-derived plastics. This study evaluates the development of bioplastics through the valorization of agro-industrial by-products from the lentil processing industry: discarded lentils not suitable for direct consumption [1], which are processed into flour (LF), and aquafaba (AF) (which is the nutrient-rich liquid waste generated during the industrial cooking and canning of legumes) [2]. This study evaluates the development of bioplastics through the valorization of agro-industrial by-products, utilizing mixtures of LF, AF and glycerol.
The bioplastics were fabricated via injection molding (T mold = 120°C; Injection pressure = 500 MPa) and subsequently the mechanical properties were determined by Dynamic Mechanical Analysis (DMA) and uniaxial tensile tests until break. DMA tests revealed a predominantly elastic behavior (E′ > E″) across all formulations, confirming the formation of bioplastics. A direct correlation was observed between flour content and the of the viscoelastic moduli. The 80:20 (flour:glycerol ratio) matrix was selected as a reference, and LF was partially replaced by AF at levels of 5, 10, and 20%. Results indicated that aquafaba induced a complementary plasticizing effect: a 10% replacement matched the viscoelastic response of the 75:25 formulation, while the 20% level approximated the performance of the 70:30 mixture. The achieved versatility demonstrates the potential of aquafaba for designing tailor-made biodegradable packaging under a circular economy model

Keywords:
Aquafaba, Bioplastics, Valorization, Lentils, Rheology.

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Acknowledgements:
These authors acknowledge to the “Asociación Universitaria Iberoamericana de Postgrado” (AUIP) for the mobility grant to E. Golzi.

Physicochemical and Functional Properties of Ginger (Zingiber officinale) Starch

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The growing demand for sustainable hydrocolloids for food structuring and biodegradable materials has intensified interest in non-conventional botanical starch sources. Although ginger (Zingiber officinale) starch has been previously described, it remains far less explored than conventional cereal and tuber starches. In this study, ginger starch was extracted and comprehensively characterized regarding composition, structure, and rheological behavior, with particular emphasis on attributes relevant to film-forming applications. The material showed an extraction yield of 8% and a relatively high amylose content (38.19 ± 0.6%). Proximate analysis indicated high polysaccharide purity, with 80.98% carbohydrates, 17.41% moisture, and minor levels of protein (0.90%), ash (0.42%), lipids (0.13%), and fiber (0.16). Optical and scanning electron microscopies revealed irregular to oval granules with heterogeneous size distribution and preserved surface integrity. X-ray diffraction confirmed an A-type crystalline pattern, while FTIR spectra displayed characteristic bands of native starch, including hydroxyl groups, C–H stretching, and glycosidic linkages. Rheological properties determined by Rapid Visco Analyzer demonstrated a high pasting temperature (93.5 ° C), indicating strong crystalline organization and resistance to thermal disruption. The elevated peak viscosity (2495 cP) combined with low breakdown (278 cP) suggested good granule stability under heating and shear, favoring the formation of homogeneous dispersions during processing. Upon cooling, the pronounced increase in final viscosity (6747 cP) and setback (4529 cP) evidenced a marked retrogradation tendency, consistent with the high amylose content and enhanced intermolecular reassociation. Swelling power increased progressively with temperature, reflecting controlled hydration without extensive granule collapse. From a functional standpoint, the combination of thermal stability, moderate swelling, and strong molecular reorganization supports the development of structured gel networks after cooling and solvent removal. These features are particularly relevant for film-casting technologies, where gelatinization behavior, dispersion uniformity, and retrogradation play critical roles in generating continuous and cohesive matrices. Overall, ginger starch exhibits gel-forming capacity and thermal resistance compatible with advanced hydrocolloid applications in biodegradable or edible materials for food packaging applications.

Keywords:
Pasting behavior, retrogradation, rheological properties

RHEOLOGICAL BEHAVIOR OF CREAM CHEESE-LIKE EMULSION PRODUCED FROM FABA BEAN PROTEIN CONCENTRATES

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A growing number of questions have emerged regarding the specific applications of plant proteins, in light of the current trend towards using them as substitutes for animal proteins. Given their protein content, there is great potential for pulses as protein sources. Furthermore, the growing interest in faba bean (Vicia faba L.) underscores its potential in food applications and particularly for dairy like products. Therefore, the main goal of this study was to produce, characterize and evaluate the rheological behavior of plant-based dairy analogue similar to cream cheese. To this end, the conditions for producing these acidified emulsions (using glucono-delta-lactone) were screened in order to determine the heat treatment temperature and homogenization pressure after acidification. The emulsions were characterized before and after heat treatment, after acidification, and after high-pressure homogenization (HPH) regarding their droplet size. The rheological behavior of homogenized acidified emulsions was then assessed by temperature, time, frequency and strain sweeps. The temperature of the heat treatment played an important role in the final texture of the cream cheese-like emulsions, whereas the pressure of the HPH process had no visual impact on their final visual texture. The average droplet size of these acidified emulsions after HPH decreased sharply after dilution in 1% SDS (from 15µm without SDS dilution to 3.4-4µm), meaning that the droplets were flocculated. Subsequent analysis of their rheological behavior revealed that cooling and isotherm phases were responsible for strengthening and stabilization of the gel, respectively. Finally, it was determined that the gels formed break when applying a 20% deformation.

Keywords:
plant-based analogues, chemical acidification, functionality, acidified emulsions, rheology

Acknowledgements:
This work benefitted of the financial support of the French government through the National Research Agency (ANR) as part of France 2030 in the framework of LETSPROSEED ANR-22-PELG-002.

Effect of Physical and Drying Treatments on Near- Infrared Spectroscopic Characterization of Starch and Protein Peaks in Ulva ohnoi with Respect to Model Spectra

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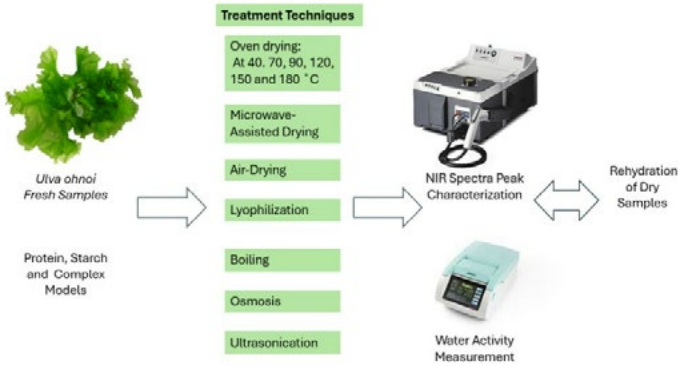
Ulva ohnoi had different drying techniques applied, including air, oven, microwave-assisted and freeze-drying (lyophilization), and three other physical treatments as osmosis, boiling and ultrasonication. The effects of these treatments on Near-Infrared NIR spectra, water activity and weight of *Ulva ohnoi* samples were studied. Also, the protein and polysaccharide (mainly starch) peaks in the obtained spectra were defined and characterized using different models.
Results showed that microwave- assisted, oven, and freeze-drying have significant effects on the spectra, with lyophilization being the most effective drying technique. Using potato starch spectrum model, three peaks and one valley corresponding to starch were detected at 4750 cm^{-1}, 5186 cm^{-1}, 6900 cm^{-1}, and 4500 cm^{-1} respectively.
In addition, three peaks corresponding to proteins were detected using model spectra. The comparison of the *Ulva ohnoi* fresh spectrum with the studied models suggests that the *Ulva ohnoi* proteins have an alfa-helix dominated secondary structure.
Moreover, after rehydration, spectra of some treated samples returned to the initial conformation as the fresh ones, which is a significant preservative characteristic for food industry. This study contributes to the growing body of research on algae as a sustainable food source, and it offers insights into the practical application of NIR spectroscopy for real time analysis of protein and carbohydrate content.

Keywords:
Physical treatment; Ulva ohnoi; NIR spectroscopy; protein and polysaccharide peak analysis; Lyophilization; Drying techniques; Sustainable novel food



Graphical abstract showing the different treatments applied on Ulva ohnoi and different models after which NIR spectra and water activity are characterized.

Acknowledgements:
The authors would like to thank the predoctoral program AGAUR-FI ajuts (2025 FI-3 00065) Joan Oro, which is backed by the Secretariat of Universities and Research of the Department of Research and Universities of the Generalitat of Catalonia, as well as the European Social Plus Fund.

Characterization and Structural Analysis of Egg Yolk Plasma

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Hen's egg yolk plasma is a complex colloidal dispersion containing lipid-protein assemblies that provide multiple functionalities in foods, i.e., emulsifying, stabilizing, and gelling. The plasma fraction consists mainly of low-density lipoproteins (LDLs, 85 %) and smaller amounts of water-soluble livetins (15 %) [1]. Although LDLs are often treated as a single class of particles, increasing evidence indicates that yolk plasma contains several LDL populations with distinct densities, sizes, and functional properties. These lipid particles and livetins appear to act synergistically, and their combined interactions are thought to be essential for the functional behavior of egg yolk.

This study reports the composition and structural organization of yolk plasma components, and shows the structure-function relationships of distinct LDL sub-populations and their interactions. Egg yolk plasma was extracted at various ionic strengths (0.1-0.35 M NaCl), and the structures present in the supernatant fraction obtained either at 10.000-40.000×g were characterized by light scattering, small-angle X-ray scattering (SAXS), and nano-differential scanning calorimetry (nano-DSC); their interfacial and gelling properties were analyzed by drop tensiometry and small oscillatory rheology. Extraction at low ionic strength (0.1 M NaCl) resulted in broad particle size distributions, whereas higher salt concentrations yielded narrower populations. The ratio Rg/Rh indicated elongated or self-associated assemblies. SAXS confirmed greater structural definition at higher ionic strengths, consistent with more uniform LDL populations. Nano-DSC revealed multiple thermal transitions between 55 and 85°C, reflecting lipoprotein fractions of different stabilities. Interfacial and rheological analyses provide additional insight into the surface activity and structural behavior of yolk plasma components.

The results suggest that yolk plasma is a heterogeneous colloidal dispersion in which several lipoprotein populations coexist and interact. Understanding how these structures relate to interfacial and thermal behavior provides new insight into the fundamental organization of natural lipid-protein assemblies.

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What is the best way to effectively extract surface active components of the lupin seeds ?

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The increasing ecological awareness of the food industry stimulates development of new food-compatible biosurfactants derived from natural and renewable resources with minimum chemical transformation. For this purpose, the plant seeds extracts rich in biosurfactants (e.g. proteins) seem to be especially promising candidates. Lupin belongs to a *Fabaceae* family and is typically cultivated for animal feed, nutritional, medicinal or ornamental purposes, as well as and for its unique ability to fix nitrogen from the atmosphere which fertilizes the soil for the subsequent crops. The high protein content of lupin seeds opens several possibilities of their use as a source of plant-derived biosurfactants. In the present study, aqueous extracts of various lupin species (blue or narrowleafed - *Lupinus angustifolius* and yellow - *Lupinus luteus*), with high ("bitter") and low ("sweet") alkaloid content were prepared using a variety of protocols. Their surface activity was assessed by measuring surface tension (γ_{eq}) and surface compression rheology parameters of the adsorbed layers (E', E''). The often contradictory effect of extraction conditions (pH program, time, seed grinding, temperature, enzymes, fermentation, etc.) on the protein recovery and surface activity will be discussed. We will show that with relatively simple modifications of the extraction conditions, the extracts can be turned into efficient biosurfactants solutions [1].

Keywords:
protein concentrate, surface tension, surface rheology, hydrolysis

Lupin plant

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Acknowledgements:
This research was funded by the National Science Centre, Poland grant nr 2024/53/B/ST4/00261

Controlled formation of casein nanoparticles by enzymatic cross-linking: Influence of cross-linking conditions

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Previous studies indicate that the self-association of non-micellar casein into hydrated nanoparticles is, apart from casein concentration, determined by various reaction conditions. Microbial transglutaminase (mTGase) catalyzes the formation of covalent bonds between glutamine and lysine residues of a protein, thus enabling the enzymatic cross-linking of caseins. This led to the hypothesis that, depending on reaction parameters, the associated caseins are able to form nanoparticles. This study aims to investigate the potential of mTGase induced cross-linking as a means to control particle size and particle properties through systematic variation of casein concentration, temperature, and ionic strength.
In this study, aqueous solutions of commercial acid casein (cNaCn) or of β-casein-rich acid casein (β-NaCn), prepared from skim milk by diafiltration, acid precipitation of the permeate at pH 4.6 and subsequent freeze-drying, were used. The powders were then diluted in demineralised water at concentrations of 10 g/kg, 27 g/kg, or 50 g/kg and adjusted to pH 6.6 with NaOH. The effects of monovalent (Na^+) and divalent cations (Ca^{2+}) were studied in the range of 0 – 1 mol/L and 0 – 0.008 mol/L, respectively. Casein nanoparticle formation was induced by cross-linking with mTGase (3 U mTGase per g protein) at 40 °C for 0 h (control), 1 h, 3 h, 6 h and 24 h. Subsequent gelation of the samples with glucono-δ-lactone was monitored in time-based small amplitude oscillatory shear rheometry and the maximum storage modulus (G'_{max}) was taken for evaluation. SDS-PAGE was used to roughly follow changes in the particle size, selected samples were analyzed by SEC-MALS and AF4.
Independent of the casein sample under study, an increase in casein concentration generally resulted in enhanced stiffness of the acid gels. In case of cNaCn, longer incubation resulted in larger nanoparticles, without an increase in gel stiffness. Gels made from β-NaCn solutions exhibited increased stiffness with prolonged cross-linking, accompanied by higher particle compactness, as determined by SEC-MALS and AF4, indicating further cross-linking within the already formed nanoparticles. Increasing ionic strength affected the association and cross-linking behavior, resulting in distinct effects of monovalent and divalent cations on nanoparticle size, G'_{max} and gelation onset. The findings suggest that the formation of casein nanoparticles by cross-linking with mTGase can be controlled by a combination of incubation time, casein concentration and ionic strength, with a significant impact exerted by the composition of the casein preparations. The resulting hydrated nanoparticles, which vary in size and density, may thus offer a high potential for a range of different applications.

Keywords:
casein Nanoparticles, microbial transglutaminase, cross-linking, ionic strength

Acknowledgements:
Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – RO 3454/5-3; LE 1424/9-3

Redesign of casein micelle for better functionality in infant formula

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There are large differences between the composition and structure of casein micelles in human milk and that in bovine milk, and these differences would significantly affect digestibility of the micelles. This study aimed to provide the current progress on the reformation of bovine milk-based casein micelles for better digestibility. Reformed casein micelles from bovine caseins simulating human casein composition and phosphorylation patterns, and reformed casein micelles from demineralized bovine micellar casein concentrate (MCC) simulating human milk mineral compositions were prepared. The particle size, micellar hydration, micellar mineralization, morphology and infant *in vitro* gastrointestinal digestibility of the reformed casein micelles were characterized. Caseins were fractionated from bovine caseins and formulated according to human casein composition, i.e., β-, κ- and α_{s1} -caseins with a ratio of 68:20:12. The formulated caseins were dephosphorylated for different times and were mixed to obtain mixed phosphorylation patterns for β-casein, showing 0-5 phosphate groups comparable to human β-casein. With the average mineral concentrations found in human milk, $CaCl_2$, $MgCl_2$, citrate and inorganic phosphate were added into the formulated casein dispersions to obtain casein micelles. The reformed micelles were close to human micelles in relation to particle size, micellar hydration, molar ratio of Ca:casein, morphology and internal structure. For gastrointestinal digestion, the reformed micelles were close to human micelles in terms of the gastric flocs, casein degradation rate, free amino groups, and molecular weight distribution of peptides. Additionally, the casein micelles reformed from the demineralized MCC also showed small particle size and improved digestibility. This study suggested efficient approaches to reform casein micelles with improved digestibility from the reformulated and dephosphorylated bovine caseins and the demineralized bovine MCC. These reformed casein micelles could be potentially used as protein and mineral supplements for the production of infant formula.

Keywords:
casein micelle, protein composition, phosphorylation, infant formula, digestion

Casein particles reassembled from decalcified bovine micellar casein concentrate: colloidal structures and digestibility in model infant formula emulsions

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Casein micelles are prone to form dense coagula during gastric digestion, leading to delayed gastric emptying and impaired digestion and absorption of caseins. Previous research has demonstrated that reducing micellar calcium level weakened gastric coagulation of casein micelles, thus improving the digestibility. However, the optimal decalcification level for casein micelles to reduce gastric coagulation and enhance digestibility in both protein solutions and emulsion systems has not been established. Colloidal structures of casein particles reassembled from 0-81% decalcified bovine micellar casein concentrate were study, and the *in vitro* gastrointestinal digestibility of bovine milk fat emulsions stabilized using these reassembled particles was investigated at infant conditions. To induce the reassembly of casein particles, citrate, calcium plus magnesium, and phosphate were added sequentially over three cycles into the decalcified MCC dispersions with 0.4% (w/v) caseins. For particles reassembled from MCC with increasing decalcification levels up to 61%, the percentages of calcium, inorganic phosphate and caseins in the non-sedimentable phase increased, the particle sizes decreased, the zeta-potential and hydration level increased, and the molar ratios of both calcium and inorganic phosphate to caseins in particles decreased. At the decalcification level above 61%, the particle sizes, hydration levels, morphologies and internal structures of the reassembled particles were similar to those of human casein micelles. During both gastric and intestinal digestion of emulsions stabilized using the particles reassembled from MCC with increasing decalcification levels up to 61%, smaller and looser coagula that released smaller fat droplets were observed, concomitant with a faster formation of free amino groups, smaller peptides, diglycerides, monoglycerides and free fatty acids. At the decalcification level above 61%, fewer fatty acids in calcium-soaps, and more fatty acids and calcium in the mixed micelle phase were found at the end of intestinal digestion. These results suggested a potential approach to reassembling human micelle analogues with small sizes and loose structures, to be used in the manufacture of infant formula with improved coagulation behavior, accelerated proteolysis and lipolysis, and greater bioaccessibility of fatty acids and calcium.

Atomic force microscopy of never-dried fat globules in bovine milk and plant-based milk analogs

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Atomic Force Microscopy (AFM) can measure delicate samples such as liquid-liquid interfaces and nanoparticles therein. We recently showed how AFM reveals the topography and nanomechanical properties of real-world Pickering emulsions. [1] This technique has now successfully been expanded to food products: milks and their plant-based analogs. Milk is a globally consumed beverage known for its texture, taste, and nutritional values. These properties vary depending on the structure of milk and milk fat globules (MFG), which are essentially emulsion droplets with interfacial particles. With our developed AFM method, it is possible to distinguish the surface structure of MFGs and how the interfaces differ between unhomogenized whole milk and ultra-high-temperature-treated milk. Whole milk MFGs have a homogenous coating (Fig. 1A) that becomes more disorganized during heat treatments (Fig. 1B). Fat globules in plant-based milk analogs (AFG) exhibit much coarser and more heterogeneously distributed coating than MFGs (Fig. 1C). Furthermore, the AFG coating varies greatly from globule to globule, and the coating can cause AFGs to form aggregates. Since the globules remain stable during storage, the aggregates likely formed during manufacturing. Besides presenting results, I will briefly introduce how AFM can prove useful for analyzing milk and milk analogs and inevitably introducing improved plant-based analogs to the market.

Keywords:
Atomic force microscopy, emulsion, milk, milk analogs, fat globules

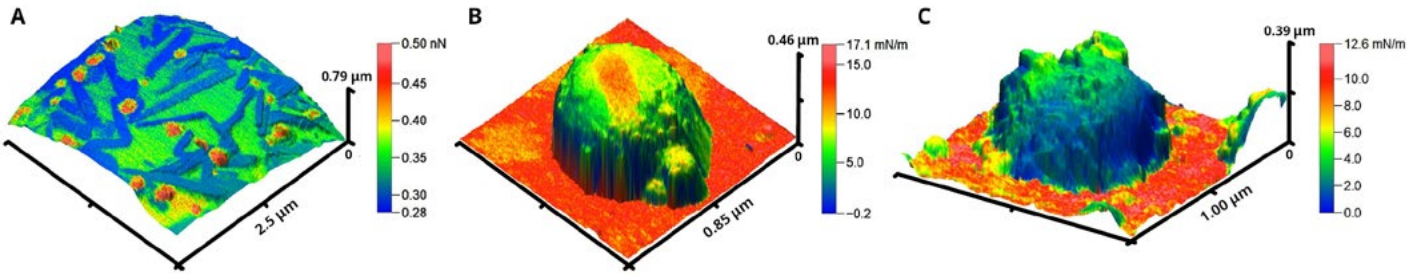

Figure 1. AFM micrographs of fat globules in an aqueous environment. (A) Unhomogenized bovine MFG with adhesion data overlay. (B) MFG from UHT-treated bovine milk with stiffness data overlay. (C) AFG from an oat-based milk analog with stiffness data overlay.

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Acknowledgements:
ERC Consolidator grant ID: 863808 “PARTIFACE”.

Understanding the structural buildup and structural changes of protein bars through imaging techniques.

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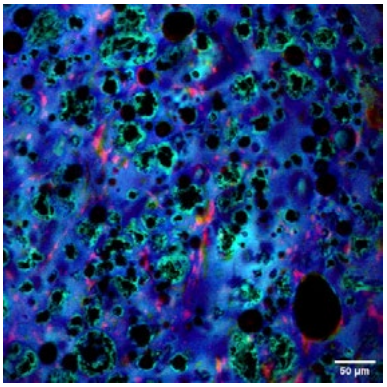
Protein bars are multiphase systems made by mixing protein powders, sugar syrups, polyols, and fat. However, the structure of a protein bar and the structural changes resulting in the hardening of protein bars are still unclear.
It is hypothesized that during mixing and early storage, protein powder particles hydrate only partially since the moisture content of the bar is low (12 %). This would result in protein powder particles with a hydrated shell suspended in a liquid phase with a limited amount of solubilized proteins. The lipid phase is also dispersed in the liquid phase, sometimes associated with air bubbles.
The structure of a protein bar is characterized by different techniques. Stimulated Raman scattering (SRS) microscopy enables label-free imaging of proteins, the liquid phase, and the fat phase. Scanning electron microscopy (SEM) and X-ray tomography are used to look at the surface morphology and understand the internal 3D structure, respectively. It has been observed that protein bars contain integer protein particles. Proteins seem to gradually solubilize in the liquid phase during the first weeks of storage. Fat particles form a separate phase, sometimes associated with air bubbles. Combining different techniques results in a clear understanding of how protein bars develop a structure and how changes in this structure happen over shelf life.
The understanding of protein bar structure, structural changes, and their relation to the texture development during storage is key to designing superior protein bars.

Keywords:
Protein bar, Dairy, Microscopy, Structure



Stimulated Raman scattering microscopic image of a nine day old protein bar. Green indicates proteins, blue indicates the liquid phase, and red indicates the lipids phase.

Acknowledgements:
This project is funded by and conducted in collaboration with Arla Foods Ingredients.
SRS-Imaging data were collected at the Center for Advanced Bioimaging (CAB) Denmark, University of Copenhagen, which is operated with funding from the Novo Nordisk Foundation (NNF23OC0082200).

Amyloid Fibrils in Thin Liquid Films

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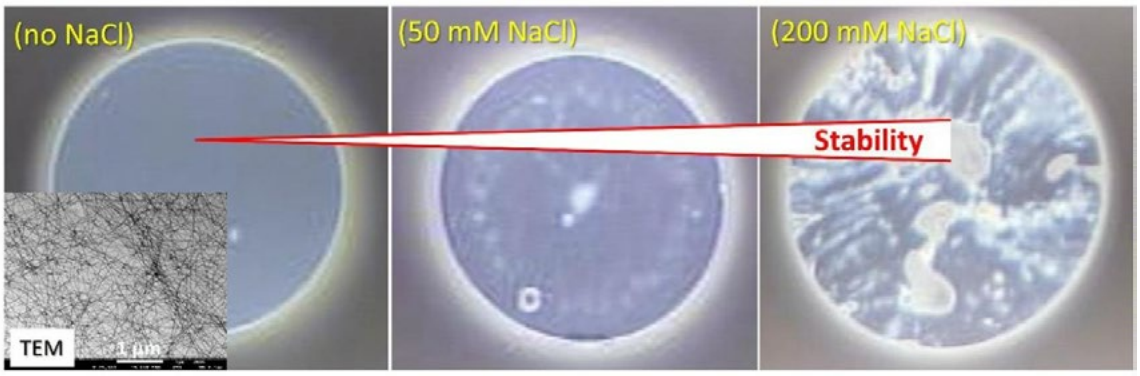
Beyond the disease-associated role of in vivo amyloids, amyloid fibrils formed from nonpathogenic, food-grade proteins have emerged as promising functional materials with exceptional physicochemical and mechanical characteristics. Amyloid fibrils act as highly efficient structuring and stabilizing agents in soft colloids such as foams and emulsions, often outperforming native proteins and non-fibrillar aggregates. Their strong interfacial activity and mechanical rigidity make them attractive building blocks for next-generation sustainable food colloids. Despite this potential, the scientific field remains fragmented. No integrated framework currently links amyloid fibril material attributes (chemical composition, molecular structure, supramolecular morphology, and physicochemical responses) to their interfacial organization, the stability of thin liquid films (TLF) separating foam bubbles or emulsion droplets, and ultimately macroscopic foam/emulsion performance. This lack of multiscale understanding limits rational design of amyloid fibrils-based food materials. Here, we report for the first time results from experiments with TLF (foam films) stabilized with amyloid fibrils (from ß-lactoglobulin) as part of a larger systematic study dedicated to elucidating the amyloid fibril-mediated mechanisms of stabilization of foams and emulsions.



Microscopy photographs in reflected light of black foam films stabilized by ß-lactoglobulin fibrils (pH 2). Film stability increases with addition of NaCl. Inset shows TEM images of the fibrils at ×25 000 magnification.

Acknowledgements:
Bilateral Polish Academy of Sciences – Bulgarian Academy of Sciences project for staff exchange 2024-2025 “Exploring the action of protein aggregates as stabilizers of soft biocolloids”.

Microstructure of dried peanut sauce depending on drying method and formulations

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The type of drying technique applied to prepare a dried and ready-to-use peanut sauce product affects the microstructure of the dried product. This study investigates the impact of different drying technologies (Spray Drying, Tunnel drying, and roller drying) on the structure of peanut sauce prepared from four peanut sauce formulations based on the main formulation of 3.3% w/v and the ratio of peanut to dextrin: 100/0, 90/10, and 50/50. The dried powders obtained by spray drying and dried flakes obtained from the other two methods were characterized using scanning electron microscopy (SEM).
The cooking time and formulations influence the surface morphology of the dried peanut sauce. The increase in the content of dextrin to 50/50 resulted in more dented particles with ridges, whereas tunnel and pan drying resulted in smoother surface structures. In some cases, phase separation was observed with an increased amount of dextrin 50/50. Although there was a difference in drying kinetics for each dryer, all the techniques resulted in the formation of pores on the surface of the particles.

Keywords:
surface microstructure of spray, tunnel and roller drying peanut sauce

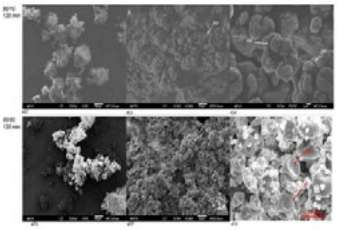

Figure 1. SEM images of spray-dried peanut sauce. The sauce is formulated with ground peanuts and maltodextrin. The ratios are 90/10 (j-l); 50/50 (p-r). Particular structures are identified as: po = pores, de = dents, sd = particles with several dents, va = valleys, cw = cell wall material, ri = rid

Acknowledgements:
The studies are supported by the Swedish International Development Agency (SIDA) in a collaborative project between Eduardo Mondlane University (Mozambique) and Lund University (Sweden).

From Liquid to Gel: One-Step Food Structuring by Freezing

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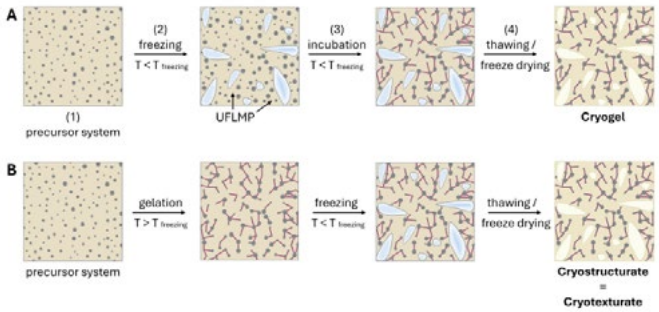
Freeze structuring (FS) is a gentle food structuring approach for designing novel food textures from unrefined raw materials by exploiting ice crystal growth and the associated cryoconcentration of solutes. While FS has been applied to a wide range of food systems, it remains unclear how freeze-induced concentration increases lead to gel strengthening or formation during freezing, limiting the use of freezing for controlled texture formation with specific outcomes.
In this work, we investigate how cryoconcentration governs two commonly distinguished freeze-induced structuring pathways: cryotexturization, where a pre-existing gel network is reorganized and strengthened during freezing and thawing, and cryogelation, where a gel forms during freezing due to concentration-driven network formation or crosslinking [1]. Using protein and polysaccharide suspensions and gels, we combine rheology, texture analysis, and real-time microstructural characterization in a Hele–Shaw cell to examine how raw-material properties influence the system's response to cryoconcentration. By comparing the resulting microstructures and mechanical properties, we aim to identify which raw material characteristics favor cryotexturization or cryogelation, and how these pathways can be modulated to design structured and stable food products using freezing as a single and gentle processing step.

Keywords:
Freezing, Food Processing, Food Structuring



Overview of two cryogenic polymer processing methods: (A) Cryogelation, where freezing triggers gelation, and (B) cryotexturization, where gelation occurs before freezing. Solvent crystallisation concentrates solutes in the unfrozen liquid microphase. Graph based on Lozinsky (2018)

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Effects of Ozone Concentration and Reaction Time on Starch: Preliminary Study of Ozonation Mechanism, Kinetics, and Process Development

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Starch needs to be modified to improve its functionality. Among various modification methods, ozone treatment has demonstrated a positive impact on starch properties. Ozonated starch can be used as a thickening and stabilizing agent for food products, improve freeze-thaw stability for frozen food products, and has potential as a food ink in 3d printing. Ozonation is considered a clean technology and provides an environmentally friendly approach for starch modification since it reacts with starch molecules at room temperature, it does not need a catalyst or any other specific conditions to react, and it has no residual toxic waste. Starch modification using ozone involves complex chemical reaction. Starch ozonation system typically consists of three different phases: gas (O3), liquid (water), and solid (starch). Meanwhile, ozone is known to have low solubility in water, it has to go through an indirect pathway in which ozone breaks down into hydroxyl radicals (OH•) before reacting with another substance. A study on the reaction mechanism and kinetics of starch ozonation process is needed to better understand the process and potentially develop a better ozonation process.
In this preliminary study, we evaluate the effects of ozone concentration and reaction time on changes in starch structure and gelatinization properties. To the best of our knowledge, there is no prior study that determine the optimal ozone concentration for starch ozonation. Previous studies used a very wide range of ozone concentration, from very low to very high levels. In this work, two ozone concentration levels were applied to corn starch to examine their effects on starch properties. Ozone was bubbled into starch-water mixture at two concentration levels (1.7 and 15.6 mgL-1). Different reaction times at 0, 1, 3, 5, 10, and 30 minutes were also studied to provide a basic information for further study on reaction mechanism and kinetics. Following treatment, the ozonated starch suspension was filtered and dried for 24 hours at 40°C in an oven before being used for further analysis. Ozone concentration entering and leaving the reactor was monitored using an ozone monitor to determine the amount of ozone involved in the reaction. Fourier Transform Infrared Spectroscopy (FTIR) was used to detect structural changes and Differential Scanning Calorimetry (DSC) was used to evaluate gelatinization properties.
The results suggested that higher concentrations leaving more unused ozone. Reaction using high ozone concentration leave a relatively large amount of remaining ozone at the outlet, while in a reaction using low ozone concentration, nearly all ozone entering the reactor was reacted with the starch suspension, leaving almost nothing at the outlet. This results indicate the needs to do optimization of the ozone concentration for starch ozonation. FTIR results showed significant structural changes, marked by increased intensities of O–H, C–H, and carboxyl bands. Significant changes have been observed at the early stage of the reaction, suggesting that starch ozonation occurs rapidly. The gelatinization temperature for native starch before ozonation treatment is at 71.14°C. 30 minutes of zonation using higher ozone concentration showed a greater increase (79.05°C) compared to the one treated with a lower ozone concentration (72.15°C). At higher concentration, the gelatinization temperature generally increased as reaction time increase, while at lower concentration an initial decrease in gelatinization was observed, followed by an increase at 10 minues. These observations are preliminary and are under further study.

Keywords:
starch modification, ozone, reaction, structural changes, gelatinization

In-Situ Structuring of Potato Starch Side Streams via Fungal Fermentation – Effects on Microstructure and Mechanical Properties of Mycelium-Based Materials.

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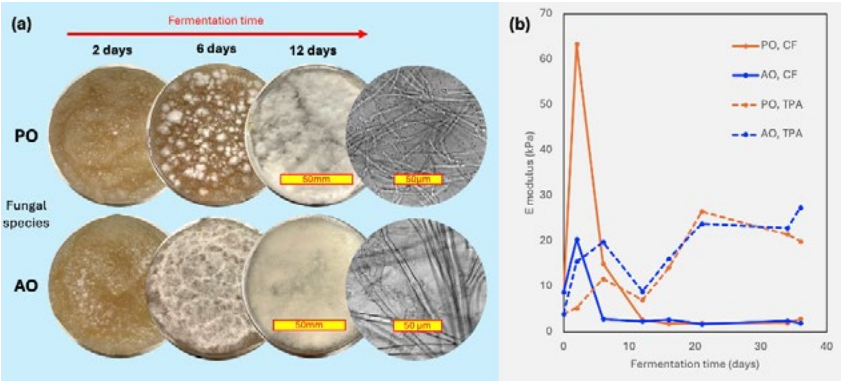
The pursuit of improved sustainability in the food system has increased interest in mycelium-based foods as resource-efficient, nutritionally balanced, and consumer acceptable alternatives to animal-derived products [1]. While mycelium is predominantly cultivated as an extractable ingredient (e.g., mycoprotein), in-situ structuring through fungal growth offers a strategy to generate novel textures within plant-based substrates. However, insufficient understanding of how fermentation conditions influence structural development and mechanical properties constrains product development [2]. In this study, three food-grade filamentous fungi (*Aspergillus oryzae* (AO), *Rhizopus oryzae* (RO), and *Pleurotus ostreatus* (PO)) were cultivated via solid-state fermentation on potato fiber bind (PFB), a starch industry by-product. AO and PO were further evaluated to assess fermentation time effects. The resulting materials exhibited structural heterogeneity, with growth concentrated near the air-substrate interface, indicating oxygen-limited growth within the bulk matrix. Microscopy revealed species-dependent differences in mycelium network organization and substrate interactions. Water holding capacity (WHC) and elasticity were evaluated using texture profile analysis (TPA) and a centrifugal filtration (CF) approach. CF yielded lower elasticity values than TPA, likely reflecting bulk properties, whereas TPA was dominated by surface-layer characteristics. Fermentation initially increased WHC and elasticity relative to unfermented PFB, likely due to enzymatic substrate modification and enhanced water retention. Prolonged fermentation reduced both parameters, with changes occurring earlier for AO (6 days) than for PO (12 days). After 12 days, AO- and PO-based materials exhibited comparable elasticity values across methods. These findings demonstrate that fungal species selection and fermentation time are key drivers of texture development in mycelium-structured potato side streams, supporting the use of filamentous fungi as biological structuring agents for sustainable food applications.

Keywords:
Mycelium-based materials, Solid-state fermentation, Biological structuring, Food side-stream valorization, Microstructure, Mechanical properties



(a) Mycelium-based materials produced via SSF with AO and PO at increasing fermentation times. Brightfield microscopy images of pure mycelium are provided. (b) Elastic modulus development over fermentation time measured using CF and TPA methods.

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Acknowledgements:
The authors would like to acknowledge funding from Independent Research Fund Denmark for project BioMyTerials (4307-00162B).

Multiscale DWS microrheology reveals microstructural weakening during thermal de-gelation of a food gelatin gel

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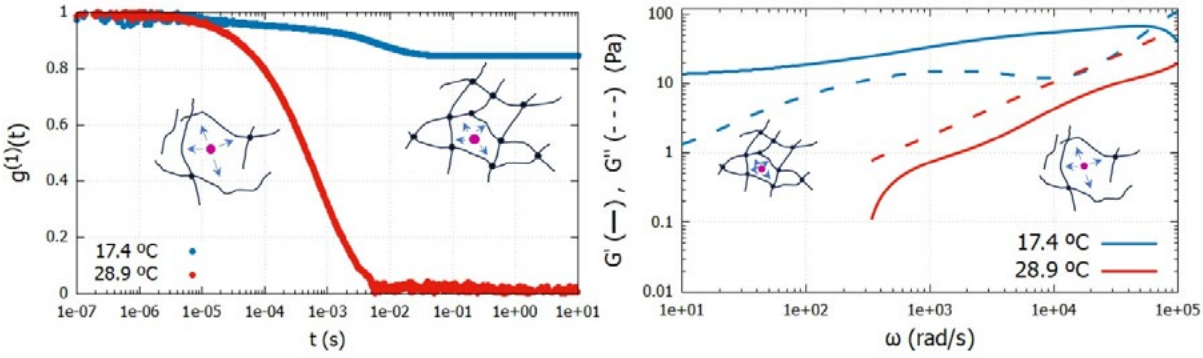
Soft foods are often highly turbid and structurally heterogeneous, making in situ microstructural characterization challenging. Here we used Diffusing Wave Spectroscopy (DWS) as a multiscale tool to quantify how a food gelatin gel progressively loses its solid-like network upon heating, transitioning to a viscous sol. A commercial gelatin gel was prepared with polystyrene tracer particles and measured by transmission DWS over a temperature range spanning gel-like to liquid-like behaviour.
At low temperature, the electric-field correlation function, $g_1(\tau)$, decays to a non-zero plateau, indicating restricted Brownian motion due to a percolated gel network. Inverting $g_1(\tau)$ yields a mean square displacement (MSD) displaying plateau for T <28°C, consistent with tracer caging within the network. Crucially, gelatin elasticity arises from reversible physical junctions associated with partially structured (helical) segments acting as effective crosslinks. As temperature increases, these junctions weaken, producing a clear microstructural signature: the cage size increases (≈30.8 nm at 17.4 °C to ≈86.0 nm at 27.1 °C), while the plateau height of the correlation function decreases.
Using passive microrheology, we obtain $G'(\omega)$ and $G''(\omega)$ and observe a simultaneous loss of elasticity: $G'(\omega)$ decreases as cage size grows, and the system evolves progressively toward viscous-dominated response. T_{gel} is obtained from our DWS measurements as the temperature at which the response becomes loss-dominated, i.e. $G''(\omega) > G'(\omega)$ over the full frequency window, yielding T_{gel} ≈28.9°C.
Overall, DWS directly links microscopic network weakening to frequency-dependent linear viscoelastic moduli, $G^*(\omega)$, obtained by passive microrheology, enabling multiscale characterization of thermally induced structural changes in soft food gels.

Keywords:
Diffusing Wave Spectroscopy; passive microrheology; gelatin gel; physical junctions; gel-sol transition; cage size; viscoelasticity.



$g_1(t)$ showing plateau at low T and its decrease with T; G'(ω) and G''(ω) at low T vs 28.9 °C highlighting G''>G'.

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Acknowledgements:
The authors acknowledge Grant No. PID2022-136540NB-I00 funded by MICIU/AEI/ 10.13039/501100011033 and ERDF A way of making Europe.

Simultaneous Multiangle DLS for Complex Wine-Based Beverages

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Wine-based mixed beverages are complex food colloids containing polyphenols, proteins, polysaccharides, sugars, and dissolved gases. Despite being widely consumed and commercially relevant, the colloidal stability and particle size distributions in these multicomponent drinks remain insufficiently characterized.
Model wine-based mixed beverages are prepared by combining red wine with carbonated soft drinks (cola and lemon soda) and water at controlled volume ratios. Dynamic light scattering (DLS) is used to determine hydrodynamic size distributions and to track composition-dependent changes in scattering intensity and correlation functions. By systematically varying the wine-to-mixer ratio, the effects of sugar content, ionic strength, and carbonation on aggregation behavior detected by DLS are examined. Practical challenges associated with optically complex, polydisperse samples are addressed, including the resolution of multimodal size distributions.
The results highlight the practical value of the simultaneous multiangle DLS device DLScat (Swabian Instruments) for heterogeneous samples. The instrument enables clear discrimination between formulations and extends measurements to kinetic studies, allowing time-dependent processes such as aggregation or restructuring to be followed under realistic conditions.

Characterization of Proteins and Lipids at Liquid/Gas and Liquid/Liquid Interface by Imaging Ellipsometry and Brester Angle Microscopy – a Review

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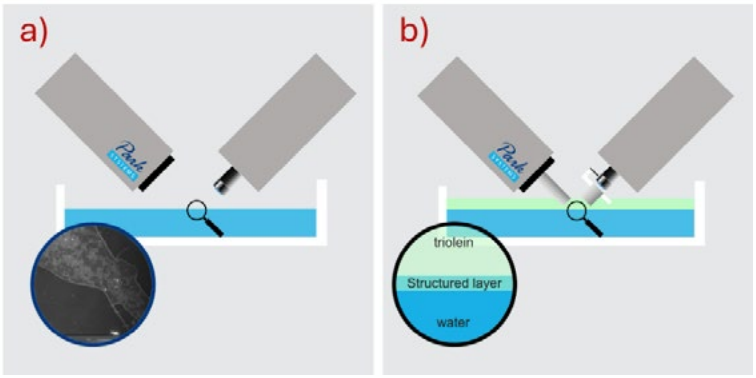
The Film thickness and morphology of protein and lipid-containing interfaces are fundamental parameters for a variety of application in food scientific and technology. Imaging ellipsometry (IE) and Brewster Angle Microscopy (BAM) are imaging and metrology techniques with unique sensitivity for thin films based on polarized light. The following application examples are suitable for demonstrating the range of possible applications in food colloids.

The layer thickness at the air/water interface, measured by imaging ellipsometer is a basic parameter for further characterized of the air-water interfacial properties and foaming functionality of Lupine protein-pectin mixtures (Xingfa Ma et al. 2025), refined rapeseed protein (Panayiotis Voudouris, 2025) Lentil protein isolate (Penghui Shen 2025). Frigerio, M. et al. (2024) studied the triolein/PB interface with ellipsometry to detect the potential formation of a confined layer with different refractive index at the liquid/liquid interface. The ellipsometric angles Delta and Psi were measured at variable angle of incidence (AOI) for the triolein PB interface at pH 6.5 and 8.9. For this characterization, the use of light guides was required.

Brewster Angle Microscopy (BAM) is state of the art in visualization of lipid films at the air water interface and Protein layers. Murray et al. (2009) revied Brewster angle microscopy of adsorbed protein films at air–water and oil–water interfaces after compression, expansion and heat processing.

The poster will provide an overview of the different methods and show current areas of application and potential new applications.

Keywords:
Imaging Ellipsometry, Imaging Spectroscopic Ellipsometry, ISE. Brewster Angle Microscopy, BAM



Scheme of the setup at the air/liquid (a) and liquid-liquid interface - with light guides (b)

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Analysis of maslinic acid nanoparticle interactions with lipid monolayers modeling cell membranes

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Maslinic acid (MA) is a natural pentacyclic triterpenoid found in olive leaves and pomace, known for its broad range of health-promoting properties, particularly its strong antitumor effects across various cancer types, as well as hepatoprotective, analgesic, anti-inflammatory, antidiabetic, antimicrobial, and anti-HIV activities. Despite its potential, its clinical application is limited by its low solubility and limited bioavailability. Formulating MA into solid lipid nanoparticles (MANPs) improves its solubility and provides a versatile functional platform for encapsulating other hydrophobic agents. We first characterize the interfacial activity and solubility of MANPs. Then, Langmuir monolayers (LMs) were used as models of healthy (Chol:DPPC:Sph = 50:35:15) and breast cancer (60:15:25) cell membranes to elucidate the molecular mechanisms governing MANP–membrane interactions. MANPs exhibited intrinsic surface activity, significantly expanding both membrane models and reducing monolayer rigidity through molecular intercalation. The results demonstrate different effects: while the healthy membrane model undergoes irreversible film disruption and hysteresis during compression–expansion cycles, the tumor model exhibits higher reversibility and stable MANP accumulation. These findings suggest that membrane lipid composition, specifically the ratio of cholesterol to unsaturated lipids, plays a critical role in modulating MANP–membrane interactions

Micro- and nano-encapsulation improving royal jelly stability during in vitro digestion and storage

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Royal jelly, a viscous substance secreted by the hypopharyngeal and mandibular glands of worker honeybees (*Apis mellifera*), is a remarkable bee product for health-promoting products. It is recognized for its exceptional nutritional value, and its reputation as a "superfood" is growing, offering numerous health benefits. However, royal jelly is highly susceptible to spoilage and, if stored under inappropriate conditions or if the cold chain is broken during storage, can deteriorate and ultimately lose its functional and commercial value. Furthermore, due to its fatty acid content, its spicy and pungent taste and odor pose a problem for consumers. Micro- and nanoencapsulation technologies have recently been considered viable alternatives for preserving the quality of bioactive compounds like royal jelly or improving their applicability in food, nutraceutical, or biological formulations. In this study, microencapsulation of royal jelly by spray drying using maltodextrin-gum arabic complex and nanoencapsulation by ionic gelation using chitosan-tripolyphosphate were carried out to determine the physical properties of micro- and nano-particles as well as release properties, *in vitro* bioaccessibility, and storage stability. The encapsulation efficiency for the microencapsulation and nanoencapsulation of royal jelly was over 94% and 73%, respectively. After spray drying, the royal jelly-loaded microcapsules had a spherical shape and generally exhibited a homogeneous distribution with a size of around 745 nm. Chitosan particles produced by ionic gelation have a particle size of 382 nm and appear in an adherent, clustered form. While the release of 10-HDA from microcapsules was linear and the highest statistically significant rate was reached at 240 min, the release from nanocapsules was slower, and the highest rate was reached at 420 min. The *in vitro* digestion test showed that the bioaccessibility of 10-HDA and total phenolic contents under simulated oral conditions was higher in nanocapsules; however, they were higher in microcapsules under simulated gastric and intestinal conditions. After 6 months of storage, the loss in 10-HDA content in microcapsules stored at 4 °C was 15.56%, while it remained at 12.06% in nanocapsules. At 25 °C storage, the loss of 10-HDA in both samples (around 22%) was similar and more limited compared to the unencapsulated sample. As a result, micro- and nano-encapsulation techniques offer a good solution for improving the stability of royal jelly.

Keywords:
Royal jelly, Microencapsulation, Nanoencapsulation, Stability, In vitro bioaccessibility

Acknowledgements:
This study was supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) with 2218 - National Postdoctoral Research Fellowship Program (121C374) and additional support for participation in the 20th Food Colloids Conference was provided by TÜBİTAK's 2224-A - Grant Program for Participation in Scientific Meetings Abroad.

Integration of Membrane Nanoprecipitation and Ethyl Lauroyl Arginate Bridging for Efficient Encapsulation of Anionic Hydrophilic Molecules in Starch Nanoparticles

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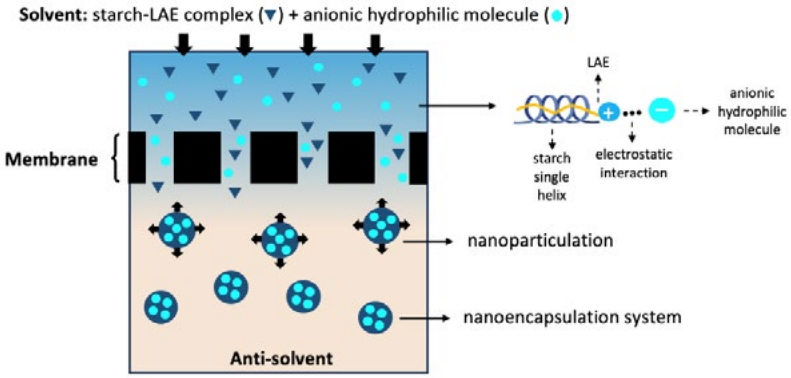
Some hydrophilic bioactive compounds in foods degrade easily under exposure to heat, light, or oxygen, resulting in poor retention and low bioavailability in complex food matrices, which limit their nutritional and sensory efficacy [1-3]. Nanoencapsulation can offer protection, controlled release, and improved stability in aqueous food systems [4]. Starch nanoparticles (**SNPs**) are food-grade, cost-effective carriers that can encapsulate target compounds via simple antisolvent precipitation [5]. Membrane nanoprecipitation (**MN**) is a process that enables controlled mixing at membrane pores, producing uniform microjets and local supersaturation, shortening mass-transfer time, and enhancing co-precipitation of small hydrophilic molecules [6]. Meanwhile, to improve the affinity between anionic hydrophilic compounds and starch in neutral aqueous environments, the food-grade cationic surfactant ethyl lauroyl arginate (**LAE**) was introduced as a bridging agent. The positively charged guanidinium group of LAE electrostatically interacts with negatively charged compounds, while its hydrophobic lauroyl chain can insert into amylose single helices via hydrophobic association, forming stable V-type inclusion complexes [5, 7-8]. This dual interaction enables strong coupling between starch and anionic hydrophilic molecules, allowing them to be effectively captured during nanoprecipitation without diffusing into the surrounding medium. The encapsulation of anionic hydrophilic compounds still remains underexplored. The goal of this study is to develop an MN-based process utilizing LAE bridging to achieve high loading and retention of anionic hydrophilic molecules in SNPs while maintaining their stability and functionality.

Keywords:
Starch nanoparticles, Membrane nanoprecipitation, Ethyl lauroyl arginate, Anionic hydrophilic compounds, Encapsulation



Schematic illustration of encapsulating anionic hydrophilic compounds into starch nanoparticles via membrane nanoprecipitation and ethyl lauroyl arginate bridging.

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Acknowledgements:
This research would be funded by the Cereal Lab at the University of Guelph and the NSERC CREATE ContRoL Program, whose contributions are gratefully acknowledged.

The composition and self-assembly structures of brain lipid extracts from mice is affected by the diet.

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Food lipid composition in our diet does affect the structure of the fat deposits in our bodies. For instance, calorie-dense diets that provoke obesity can lead to triacyl glycerol saturation and a closer packing of these lipids in adipose tissue (1). The brain contains a rich variety of lipids which, through self-assembly, are responsible for its intriguing structure through self-assembly. The link between the brain functions and nano-structures controlled by lipid composition is not yet understood (2). Clearly a range of factors affect the structure apart from the lipid composition, including the cholesterol content, the composition of salts, and temperature (3). Certain patterns in lipid composition observed in the blood have been linked to Alzheimer Disease diagnosis (4). Food, in particular certain berries, have been suggested to act as neuro-protectants (5). Any consequent changes in lipid composition are bound to be reflected in differences in the lipid self-assembly structure and in the modification of the microenvironment and pathogenesis of Alzheimer's Disease (6,7).We have performed Small Angle X-ray diffraction on brain tissue and brain lipid extract from mice that has been exposed to different diets: 1.) HT: heat-treated high-fat (HF) control diet, 2.) BB: HF with blueberries, 3.) BC: HF with black currants. The differences observed in the SAXS results have been correlated to the lipid composition analysis using thin layer chromatography and mass spectrometry. Mice fed blueberries showed increased concentrations of sphingomyelin (SM) and ergosterol compared to the control mice and mice fed with black currant. These lipids promote the formation of lamellar phase. We have shown that lipid composition in the brain and hence the lipid self-assembly can be affected by the diet.

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Acknowledgements:

We acknowledge financial support from Maja and Erik Lindqvist Research foundation as well as from NanoLund.

Effect of high pressure homogenization, ultrasonication and high hydrostatic pressure on allergenicity and bioaccessibility of sesame cake proteins

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In this study, effects of different modification techniques including ultrasonication (2, 4 or 6 min at 95% amplitude), high pressure homogenization (50, 100 or 150 MPa) and high hydrostatic pressure (0.1, 200, 400 or 600 MPa for 5 min) on allergenicity and bioaccessibility of sesame cake proteins were investigated. Untreated protein was tested as the control sample. Allergenicity test was applied using the allergen kit and approved protocol. *In vitro* bioaccessibility of the modified proteins was performed by three-stage digestion technique by determination of peptide concentration and amino acid profiles. The amount of protein released in the stomach and intestinal environments of ultrasound-modified proteins increased significantly compared to the control sample as positively correlated with the process period. The protein release rate in the model stomach and intestinal environment was 34.66-39.67% and 64.04-74.78%, respectively and was also positively affected from the high pressure homogenization. On the other hand, high hydrostatic pressure application at 600 MPa for 5 min reduced the protein release. Amino acid composition of the modified proteins was influenced from in vitro digestion. While some amino acids (phenylalanine and isoleucine) were not detected at stomach stage, they were detected after the intestinal digestion. The highest number of amino acids was detected in proteins modified by high pressure homogenization. The allergen level of control sesame protein prepared at pH 7.0 was determined as 41.13 μg/mL and was affected by the modification processes. Considering ultrasound application, the allergen level decreased and the lowest value, 28.39 μg/mL, was detected with 6 min of ultrasound application. The highest reduction at allergen level (30.58 μg/mL) by the high pressure treatment was determined at 150 MPa. High hydrostatic treatment was also procured significant reductions on allergenicity levels. In conclusion, this study showed that sesame cake proteins were effectively modified by high pressure homogenization, ultrasonication and high hydrostatic pressure techniques, by resulting in better *in vitro* bioaccessibility and lower allergenicity values.

Keywords:
Sesame protein, protein modification, non-thermal techniques, bioaccessibility, allergenicity

Acknowledgements:
This research was supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) under project number TOVAG 120O773. The authors also acknowledge financial support from the TÜBİTAK 2224-A International Scientific Events Participation Support Program.

From algae to meat analogues: texture insights using electrospun microfibers of Spirulina in meat-free deli ham

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Vegetarianism has expanded considerably to reduce environmental impact and support sustainable food production [1]. Moreover, the increasing demand for meat-like products requires continuous innovation in the food industry to develop novel formulations, technologies, and ingredients that meet consumer expectations for taste, nutritional value, and, particularly, the most significant challenge: mimicking the texture of meat products. Thus, alternative high-protein foods from actors in biodiversity and the oceans must be smart-driven and sustainable [2]. In this context, Spirulina (SP) is suitable for this purpose, as it has a high protein content and vitamins such as niacin, ascorbic acid, and riboflavin, as well as C-phycocyanin (C-PC), a bioactive compound with antioxidant properties. After C-PC extraction, a residual biomass (Spirupower ®, SPW) is obtained, which maintains nutritional value and drives forward the circular economy through a zero-waste concept. Accordingly, this study aimed to develop and evaluate the texture, mineral bioaccessibility, and protein digestibility of meat-free deli ham incorporating electrospun microfibers as carriers for SP and SPW at 5.77%. Results demonstrated that microfibers improve the texture of meat-free deli ham. The SP and SPW formulations achieved protein contents around 16% and high protein digestibility (>89%), with SPW reaching 95.01%. Mineral bioaccessibility ranged from 45.24 to 89.05%, with Fe accessibility increasing from 45.2% in the control to 70.1% in SPW. Additionally, antioxidant capacity rose significantly after in vitro digestion, particularly for SP and SPW samples.

Keywords:
Electrospinning, algae microfiber, meat analogue, texture, vegetarian

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Acknowledgements:
This work was supported by the Brazilian Foundations CAPES (Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) process number 001, FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) process nº 2023/08525-7, 2023/00857-0, 2022/06293-9, and 2020/06732-7, also CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) grant number 405238/2025-8. ARC Braga (PQ 305518/2024-0) was recipient of research productivity fellowship from CNPq.

Colloidal Design of Electrospun Biopolymer Composites for Postbiotic Delivery Systems

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Postbiotics, defined as inactivated microorganisms or their components, are gaining recognition for their health-promoting properties, including gut regulation and modulation of inflammation [1]. Beyond their biological benefits, postbiotics improve product stability, extend shelf life, and minimize adverse interactions with food matrices. Naturally present in fermented foods, they are increasingly investigated for applications in infant nutrition and active food packaging due to their antimicrobial and bioactive potential. Conventional approaches, such as emulsions, hydrogels, and nanostructures, offer varying advantages in terms of biocompatibility and food integration [2]. This study focused on developing novel polymeric matrices for postbiotic encapsulation within electrospun composites. The morphology of the polymer composites was studied using a scanning electron microscope (SEM). Fourier transform infrared spectroscopy using the attenuated total reflectance (ATR-FTIR) of the composites was used to investigate possible structural interactions in the samples. The thermal stability (TGA) of the composites was also evaluated. The results present different composites combining zein/PEO or PEO/NaCl as a polymeric base, incorporating the tributyrin or cell fragments. The SEM images show that, for these formulations, the fiber morphology depended on the solution composition. As expected and reported in the literature, variations in the composition of the polymeric solution can significantly affect the morphology of electrospun composites [3]. FTIR analysis of all produced samples showed that the composites exhibit characteristic bands of PEO and Zein, with some characteristic bands of the other components also identified. TGA analyses revealed a multi-stage weight loss curve for all samples. However, the zein/PEO composite samples exhibit more stages than the PEO/NaCl composite samples. By leveraging advanced delivery technologies, postbiotics can overcome key limitations of probiotics, such as viability challenges. Innovations in this field hold significant promise for enhancing postbiotic stability, bioavailability, and targeted functionality, paving the way for personalized health solutions.

Keywords:
Electrospinning, metabolites, tributyrin, cell fragments

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Acknowledgements:
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Aging stability and in vitro digestion release of blue maize polyphenolics microencapsulated by spray drying

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Due to high content of anthocyanin (ACNs) in the pericarp and/or in the aleurone layer of the grain, blue maize can be promising contributor of bioactive compounds in food and pharmaceutical products. Whole-grain flour of blue maize has been primarily applied in bakery and confectionery production, while the potential application of ACNs, which requires their isolation from maize grains, represents a challenge that can be attributed to their limited stability against numerous factors. One approach to overcome this difficulty is the encapsulation process of maize polyphenolics. This research aimed to examine the aging stability and *in vitro* digestion release of blue maize phenolic compounds microencapsulated by spray drying with maltodextrin (MD) and hydroxypropyl-β-cyclodextrin (HPCD). Liquid blue maize extract was spray-dried with MD (30%), HPCD (30%) and their combination (15% MD and 15% HPCD) as carrier agents. The content of total phenolic compounds and phenolic acids after accelerated aging of microencapsulates, as well as the oral bioavailability of anthocyanins (total and individual) in different *in vitro* digestion stages was analyzed. Furthermore, analysis of the thermal properties, as well as FTIR spectra of the spray-dried powders was performed. According to the results, HPCD, as well as the combination of MD and HPCD, showed a lower ability to bind phenolic compounds, but also their higher preservation during the process of accelerated aging compared to MD as single carrier. The content of total phenolic compounds and phenolic acids in spray-dried maize extract (SME) and microencapsulates with MD, HPCD and MD+HPCD was 35506, 32211, 31308 and 30622 mg CE/kg, i.e 389, 311, 307 and 285 ug/g, respesctively. After accelerated aging, phenolic acids were not detected in SME, while the content of total phenolic compounds in it was lower by 3.8%, and in microencapsulates with MD by 5.6%. A decrease in the content of total phenolic compounds and phenolic acids in both HPCD-based microencapsulates after accelerated aging was not recorded. In addition, spray-dried microencapsulates with HPCD possessed the highest thermal stability, up to 220°C, indicating good preservation of the polyphenolic structure in the temperature region important for food processing. Different carriers also showed different affinity for anthocyanins. The lowest content of total anthocyanins, especially their acylated forms, was measured in microencapsulates with MD+HPCD. However, the most stable content of anthocyanins in fluids of different *in vitro* digestion stages was recorded during the simulation of the digestion process of these microencapsulates. In the oral+gastric stage, 45, 50, 55 and 95% of Cy-3-6Mal-Glu, as the dominant blue maize anthocyanin, was released from SME and microencapsulates with MD, HPCD and MD+HPCD, while the content of this anthocyanin in the final fluids was 12, 15, 19 and 42% of the initial value, respectively. Although anthocyanins isolated from blue maize showed high stability under accelerated aging conditions, the used biopolymers showed a good impact on the stability of microencapsulates against adverse environmental conditions, primarily high temperatures.

Keywords:
Blue maize, polyphenolics, microencapsulation, aging stability, oral bioavailability

Acknowledgements:
This study was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-136/2025-03/200040 and 451-03-136/2025-03/200003).

ENCAPSULATION BY COAXIAL SPRAY-DRYING OF OLEA EUROPAEA HYDROLYSATE EXHIBITING DPP-IV INHIBITORY ACTIVITY

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Functional foods containing antidiabetic peptides have gained attention as a complementary strategy to support glycemic control in type II diabetes mellitus, projected to affect nearly 700 million people worldwide by 2045. Peptides that inhibit dipeptidyl peptidase-IV (DPP-IV) are particularly relevant, as they extend the half-life of incretin hormones, including glucagon-like peptide-1 (GLP-1) and gastric inhibitory polypeptide (GIP), which stimulate insulin secretion in the pancreas, thereby improving glycemic control without drug-related side effects. Nevertheless, incorporating antidiabetic peptides into food matrices remains challenging, as their bioactivity and bioavailability are compromised by degradation during processing, storage, and gastrointestinal digestion. Encapsulation offers an effective solution, as it could safeguard antidiabetic peptides during food processing, storage, and digestion. Previous research has primarily relied on monoaxial spray-drying, using two-fluids nozzles or rotary atomizers. Nonetheless, coaxial spray-drying using a three-fluids nozzle remains largely unexplored, despite its potential to form core–shell microcapsules via the simultaneous drying of two liquid formulations. This approach could improve peptide protection by limiting migration to the capsule surface, which enhances stability, while also offering the potential for controlled release.
Thus, the aim of this study was to investigate the encapsulation of an antidiabetic protein hydrolysate using coaxial spray-drying. The effect of different core-to-shell feed flow rate ratios (1:1, 1:2, and 1:4) was evaluated, where the core feed consisted of the hydrolysate combined with Arabic gum, while the shell was composed solely of Arabic gum. The hydrolysate, with a 20% degree of hydrolysis, was obtained via enzymatic treatment with Alcalase and Flavourzyme of olive pit flour, thus valorizing a by-product of the olive oil industry. The microcapsules obtained were characterized in terms of particle size, morphology and structure. The stability of the capsules was evaluated over nine months at 45 °C by *in vitro* determination of DPP-IV inhibitory activity, using monoaxial capsules and the unencapsulated hydrolysate as controls.
Scanning electron microscopy revealed spherical microcapsules with wrinkled surfaces, with surface roughness being more pronounced in coaxial capsules with higher core-to-shell feed flow rate ratios. All microcapsules exhibited a similar particle size distribution, predominantly in the range 0.5–4 μm, with a relatively broad dispersion extending to larger particles. Confocal microscopy confirmed the formation of core–shell structures in coaxial microcapsules, with shell thickness showing a gradual tendency to increase with higher core-to-shell ratios. *In vitro* DPP-IV inhibitory activity showed that both monoaxial and coaxial microcapsules effectively preserved the stability of the peptides at all tested ratios during 9 months of storage at 45 °C, whereas the unencapsulated hydrolysate completely lost its bioactivity after the first month. The results of this study contribute to advancing the application of coaxial spray-drying, which has so far been mostly studied in pharmaceutical contexts, for the encapsulation of bioactive ingredients with potential in the food industry.

Keywords:
Bioactive peptides, encapsulation, spray-drying, three-fluids nozzle, core-shell microcapsules

Acknowledgements:
This work was supported by the Spanish Ministry of Science, Innovation and Universities through the project PID2023-146901OB-I00.

ENCAPSULATION OF ECHIUM OIL BY ELECTROSPRAYING AND MONO- OR COAXIAL SPRAY-DRYING USING PLANT PROTEIN HYDROLYSATES AS EMULSIFIERS

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The development of functional foods enriched with omega-3 polyunsaturated fatty acids (PUFAs) remains of significant interest to the food industry. However, important technological limitations still hinder the effective incorporation of these bioactive ingredients into food matrices, mainly due to their hydrophobic nature and low oxidative stability. In this context, the production of powdered encapsulates represents one of the most promising strategies to reduce lipid oxidation during the processing and storage of foods fortified with omega-3 PUFAs. Spray drying (in its monoaxial configuration) is the most widely used encapsulation technique for producing powdered encapsulates of thermolabile ingredients, due to the maintenance of droplets at wet-bulb temperature during the constant drying rate period, short drying times (< 30 s), and high productivity. Nevertheless, this technique has been scarcely investigated for the encapsulation of thermolabile compounds in its coaxial configuration, which enables the production of core–shell structured particles, further minimizing bioactive degradation. Recently, electrohydrodynamic drying techniques such as electrospraying, which do not require heat for drying, have also emerged as potential alternative encapsulation methods.

Therefore, the aim of this study was to investigate the encapsulation of echium oil, an oil rich in omega-3 polyunsaturated fatty acids, using spray-drying (monoaxial and coaxial configurations) and electrospraying. Protein hydrolysates obtained from food industry by-products (grape seed flour and brewer's spent grain) were used as emulsifiers, while glucose syrup DE38 and maltodextrin DE 19 were employed as the encapsulating materials. Capsule characterization was performed in terms of particle size, morphology, and structure using scanning electron microscopy (SEM) and confocal microscopy, and oil encapsulation efficiency was determined. The oxidative stability of the obtained capsules was evaluated by electron paramagnetic resonance (EPR) spectroscopy over 28 days at 40 °C.

The results showed the formation of spherical particles with all the techniques studied. Capsules produced by electrospraying exhibited smaller particle size (< 2 μm) and narrower size distribution compared to those obtained by spray drying. In contrast, encapsulation efficiency was higher for spray-dried capsules (> 80%), which correlated with their greater oxidative stability. Furthermore, microcapsules produced using brewer's spent grain hydrolysate, due to its higher emulsifying activity, showed higher oxidative stability than those produced with grape seed meal hydrolysate. Interestingly, for capsules stabilized with grape seed hydrolysate, coaxial spray-drying improved both encapsulation efficiency and oxidative stability compared to monoaxial configuration. This improvement was attributed to enhanced formation of the external glucose syrup layer in the core-shell capsules obtained, which reduced the presence of surface oil droplets and improved protection against oxidation.

Keywords:
Omega-3 fatty acids; nano-microencapsulation; lipid oxidation; three-fluids nozzle; electron spin resonance

Acknowledgements:
This work was supported by the Spanish Ministry of Science, Innovation and Universities through the project PID2023-146901OB-I00.

Bovine Serum Albumin – Carrageenan Complexes as Nanocarriers for VD3 Nutrient

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Polysaccharide–protein complexes are promising delivery systems for bioactive compounds in food applications. In this study, we investigated nanogels formed by electrostatic co-assembly of carrageenan (CAR) and bovine serum albumin (BSA), where BSA acts as a macro-ionic crosslinker. Two carrageenan types, κ-carrageenan (κ-CAR) and λ-carrageenan (λ-CAR), were investigated due to their different charge densities, physicochemical and rheological properties.
Unloaded and vitamin D3 (VD3)-loaded nanogels were characterized under various conditions using small-angle X-ray and neutron scattering, complemented by spectroscopic techniques. Complex formation occurred at acidic pH, with protein dominating the nanogel structure. VD3 enhanced complexation and improved stability, even above the protein isoelectric point. Both systems formed solvent-swollen structures; κ-CAR produced larger, elongated aggregates, while λ-CAR resulted in smaller, flatter ones.
Spectroscopic analysis confirmed efficient encapsulation and release of VD3 and revealed changes in the protein secondary structure. These results demonstrate how carrageenan type and bioactive loading control nanostructure and stability of formed complexes, highlighting the potential of CAR–BSA nanogels as delivery systems for nutritional ingredients in food colloids.

Keywords:
Carrageenan, BSA, Polysaccharide-Protein Complex, VD3 Encapsulation, SANS, Contrast Matching

Acknowledgements:
The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101034266.

Nanoemulsions as a strategy for protection and delivery of the natural blue pigment C-Phycocyanin

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The use of naturally derived blue colorants remains challenging due to the scarcity and instability of blue pigments in nature. C-phycocyanin (C-PC), a protein–pigment complex found in *Spirulina* (*Arthrospira platensis*), is a promising alternative to synthetic blue dyes; however, its low stability, particularly in liquid food systems, restricts industrial application and highlights the need for effective stabilization using e.g. strategies such as nanoemulsion (NE)-based delivery systems [1]. In this study, C-PC was extracted using clean and sustainable methods (freeze–thaw cycles, centrifugation, and ultrafiltration) with water as the only solvent and incorporated at different concentrations (0.25% – NE 0.25, 0.5% – NE 0.5, and 1.0% - NE 1.0) into ultrasound-produced NE formulated with sunflower oil and Tween 80 [2]. The NEs were stored under ambient conditions with daylight exposure for 28 days and characterized in terms of colour stability (ΔE), entrapment efficiency (EE), droplet size (DS) and distribution, and zeta-potential (ZP). *In vitro* digestion behaviour and C-PC bioaccessibility were also assessed. Increasing C-PC concentration resulted in a progressive increase in DS, with mean values of approximately 95.42 nm (NE 0.25), 102.97 nm (NE 0.5), and 119.67 nm (NE 1.0), along with improved colour stability, reflected by lower ΔE values after storage. All formulations maintained ZP values below −20 mV and EE close to 90% throughout storage. During digestion, NE DS remained stable in the gastric phase but increased in the intestinal phase. NE 0.25 showed the highest bioaccessibility (45.83%), whereas NE 0.5 and NE 1.0 exhibited lower values (32.11% and 35.16%, respectively). The concomitant increase in DS and reduction in bioaccessibility at higher C-PC concentrations suggest preferential localization of C-PC at the NE interfacial layer. Overall, these results demonstrate that NEs effectively enhance C-PC entrapment, stability, and delivery, supporting their application as natural alternatives to synthetic blue colourants in food systems.

Keywords:
Nanoemulsion, Natural blue colourants, Bioaccessibility, Spirulina, Encapsulation efficiency, In vitro digestion

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Acknowledgements:
This study was supported by the Portuguese Foundation for Science and Technology (FCT) under the scope of the strategic funding of UIDB/04469/2020 unit, the project ESSEntial (DOI: 10.54499/PTDC/BII-BTI/1858/2021), and by LABBELS – Associate Laboratory in Biotechnology, Bioengineering and Microelectromechanical Systems, LA/P/0029/2020. Authors also acknowledge the project VIIAFOOD for its Assistant Research program under the scope of "Agenda para a Inovação Empresarial – VIIAFOOOD – Plataforma de Valorização, Industrialização e Inovação comercial para o Agro-alimentar" (Project n.° 37, application n.° C644929456-00000040) funded by the Plan for Recovery and Resilience (PRR) and by the European Funds Next Generation EU.

Structural integrity of phospholipid-based liposomal and oily dispersions under in vitro digestion conditions

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The effectiveness of orally-administrated bioactive compounds is strongly influenced by the ability of applied colloidal delivery systems to withstand gastrointestinal processing while preserving the colloid particle characteristics that favour absorption. This study compares the digestive behaviour of two commercially relevant phospholipid-based oral formulations: a nanoscale liposomal system and a phospholipid-stabilised triglyceride oil dispersion. A standardised *in vitro* digestion protocol representing oral, gastric, and intestinal phases was applied to evaluate particle evolution under physiologically relevant enzymatic and bile salt conditions. Structural responses were assessed through dynamic light scattering, cryo-TEM, and quantification of lipolysis progress.
The liposomal formulation exhibited notable resistance to digestive stress, maintaining a narrow size distribution below 200 nm and preserving microstructure throughout simulated digestion, even in the presence of phospholipase activity and bile salts. Conversely, the oil-based dispersion underwent pronounced restructuring during intestinal digestion, characterised by extensive lipid breakdown, marked particle size reduction, and sustained heterogeneity. These contrasting behaviours highlight the importance of formulation architecture in determining gastrointestinal stability.
Overall, the findings demonstrate that nanoscale phospholipid liposomes produced using scalable manufacturing approaches provide superior structural robustness during digestion compared to mixed lipid oil dispersions. Their maintained nanoscale dimensions following digestion suggest a potential favourable interaction with intestinal transport barriers (e.g., intestinal mucus), supporting their suitability as oral carriers for enhancing the uptake of nutritionally and biologically sensitive compounds. This colloidal system shows strong potential for application in dietary supplements, functional foods, and specialized nutrition strategies aimed at improving bioavailability in both general and at-risk populations.

Keywords:
phospholipid, liposome, commercial formulations, oral administration, in vitro digestion

Acknowledgements:
We are grateful to Frédéric Carrière (CNRS, UMR7281, Marseille, France) for his guidance on colipase purification and the application of PLA2 under simulated intestinal digestion conditions. We would like to acknowledge that liposome samples were prepared by Sergiusz Klimuszyn at Lipid Systems sp. z o.o., whereas cryo-TEM images were provided by Aleksander Foryś at the Centre of Polymers and Carbon Materials, Polish Academy of Sciences, ul. M. Curie-Sklodowskiej, 41-819 Zabrze, Poland.
This research was financially supported by the National Centre for Research and Development grant (FENG.01.01-IP.02-1718/23) to M.P. and M.L. The work at Gdańsk University of Technology was funded in part by the National Science Centre, Poland under the OPUS call in the Weave programme (research grant number 2022/47/I/NZ9/02749 to A.M).

Drying kinetics and particle morphology development of biopolymers solutions: insights from single droplet drying

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Spray-drying is the most common technique used to produce food powders from liquids. This is due to the relatively mild processing conditions required and the high throughput obtained when scaled up. Nevertheless, the complexity of spray-drying process (numerous polydisperse droplets, collisions and short residence time) does not allow studying the drying kinetics which, together with the composition of the liquid feed, influence the properties of the powder obtained. In this sense, single droplet drying analyses provide insights on one droplet drying dynamics, which might facilitate optimization of spray-dried powder properties such as morphology.

Therefore, this work aimed at investigating the drying kinetics of biopolymers solutions using two complementary approaches: sessile single droplet drying and electrodynamic levitation. Arabic gum, whey, maltodextrin DE 5-8, maltodextrin DE 18 and glucose syrup DE 38 were the biopolymers selected since they are commonly used in the production of food powders. The single droplet drying methods enabled the determination of evaporation rates [1], Peclet numbers, and locking-point times across polymers of different molecular weight and composition. Distinct drying behaviors were observed between biopolymers, with Arabic gum and whey exhibiting higher Peclet numbers and faster crust formation, whereas maltodextrins and glucose syrup showed slower evaporation and more homogeneous shrinkage. These results are also discussed in terms of the surface activity and interfacial dilatational rheological response of the biopolymers, which can influence the properties of the crust formed during drying. Finally, the morphology of the particles obtained from the sessile single droplet drying method and that of microparticles produced by spray-drying at lab scale were compared. The correspondence between single droplet drying dynamics and final morphology confirms the predictive value of these techniques for understanding and engineering powder structure. These results highlight the potential of integrating interfacial characterization with controlled single droplet drying analyses to rationally design food powders with tailored microstructures.

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Acknowledgements:

The authors acknowledge projects PID2023-146901OB-I00, PID2023-149387OB-I00, FENIX (PID2023-151668OB-I00) funded by MICIU/AEI/10.13039/501100011033, as well as partial funding from PTA2023-023684-I, by University of Granada Plan Propio through Excellence Research Unit Earth Science and Singular Laboratory AGORA (LS2022-1) programs and C-EXP-187-UGR23 awarded by Consejería de Universidad, Investigación e Innovación and by ERDF Andalusia Program 2021-2027.

Interfacial interaction of Bile Salts with emulsifiers under simulated duodenal conditions

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Bile salts (BS) are biosurfactants that play a fundamental role in lipid digestion and absorption by modulating the oil-water (O/W) interface. This study provides a detailed characterization of the interfacial behavior of Sodium Taurocholate (NaTC) and Sodium Glycocholate (NaGC), while also evaluating their interactions with Whey Protein Isolate (WPI) and a Dextran derivative (DEX). The interfacial properties were analyzed using pendant drop tensiometry under simulated duodenal conditions (pH 7.0). Additionally, sequential adsorption experiments were conducted to investigate the ability of BS to displace pre-adsorbed emulsifier layers. The experimental data were fitted to theoretical adsorption models using the IsoFit software to gain deeper insights into the adsorption mechanisms.
The results reveal that both NaTC and NaGC adsorb rapidly and irreversibly at the O/W interface, with NaTC demonstrating a higher affinity compared to NaGC. The adsorption isotherms were best described by the Reorientation A Model, which suggests that bile salts adopt a planar conformation at the interface, a finding consistent with previous literature. Sequential adsorption experiments highlighted distinct mechanisms depending on the nature of the emulsifier layer. In the BS-WPI system, bile salts penetrated the viscoelastic protein network, disrupting protein-protein interactions and partially displacing WPI from the interface through an orogenic displacement mechanism. In contrast, the BS-DEX system exhibited a different behavior, where the Dextran layer acted as a steric barrier that limited BS adsorption. Unlike the protein layer, the polysaccharide was not fully displaced, indicating a competitive adsorption mechanism dominated by steric hindrance and hydrophilic interactions.
These findings underscore the critical role of the initial emulsifier layer in determining the accessibility and adsorption behavior of bile salts at the interface. This study contributes to a deeper understanding of the interfacial dynamics of bile salts, which is essential for advancing knowledge in lipid digestion and the design of functional emulsifiers for food and pharmaceutical applications.

Keywords:
bile salts, adsorption, desorption, interfacial tension, dilatational elasticity, dextran, WPI

Acknowledgements:
This work was funded by C-EXP-187-UGR23 awarded by Consejería de Universidad, Investigación e Innovación and by ERDF Andalusia Program 2021-2027 and by PID2023- 149387OB-I00 awarded by MICIU/ AEI/10.13039/501100011033and ERDF, a way of making Europe. J.M.V. acknowledges COST-Action INFOTECH-DATA CA24145.

Unraveling curcumin adsorption in a lipid membrane model using Langmuir monolayers and atomistic Molecular Dynamics Simulations

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Curcumin is a natural polyphenol derived from *Curcuma longa* characterized by antioxidant, anti-inflammatory, analgesic, antiseptic, antiviral, and anticancer properties. The study of its interaction with lipid membranes is essential to elucidate its mechanism of action. In this work, we demonstrate the specific advantages of combining Langmuir monolayers (LM) and Molecular Dynamics (MD) simulations to investigate these interactions. The LM technique allows for fine control over membrane model composition and packing, and enables quantification of thermodynamic stability through the analysis of their surface pressure-area isotherms and the morphological analysis using Brewster angle microscopy and AFM. Complementary all-atom MD simulations provide atomistic insights into the molecular orientations and insertion dynamics that are difficult to visualize experimentally. Our experimental results show that curcumin enhances cohesion and thermodynamic stability in a lipid monolayer membrane model. These findings are supported by MD simulations, which reveal that curcumin attaches to lipid headgroups via electrostatic interactions, inserting deeper into the membrane as surface pressure increases, often adopting a planar orientation parallel to the interface. Together, these techniques offer a comprehensive understanding of curcumin–lipid monolayer interactions as a model of the first barrier of cells, providing crucial molecular insights that can be used to improve its therapeutic and nutraceutical properties.

Assignment of NMR Relaxation Time Distributions in Foods

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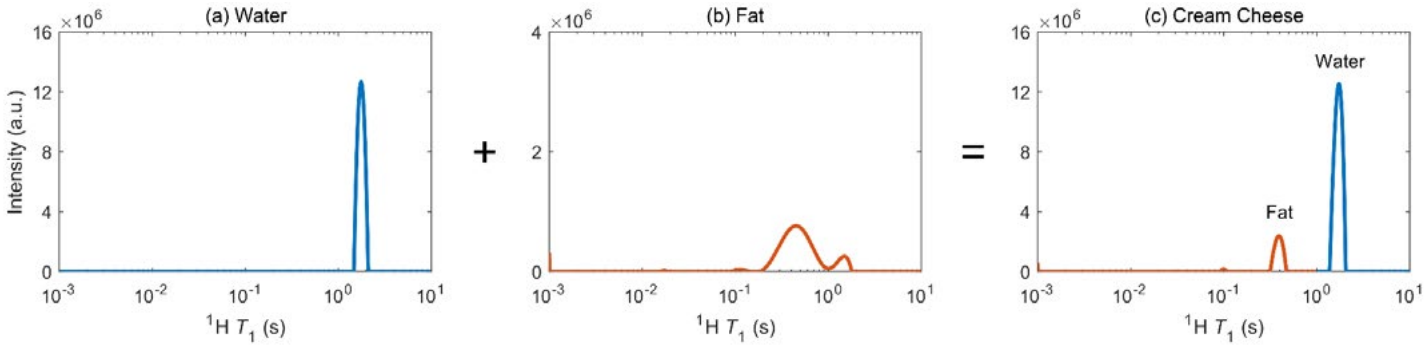
Nuclear Magnetic Resonance (NMR) is a versatile tool in research and quality control in the food industry. Most low-field NMR systems used in foods are limited to measuring ^{1}H T_1 and T_2 relaxation time distributions because of insufficient static magnetic-field homogeneity and internal gradients in heterogeneous matrices. These distributions often show multiple peaks that reflect distinct or overlapping signals from components or microenvironments. *The assignment of these peaks remains a significant challenge, but is critical for linking physicochemical properties to NMR parameters.* We present a comprehensive workflow that employs sample-centered experimental design, robust multi-exponential analysis [1, 2], multidimensional NMR [3], microstructural imaging, and physics-based simulations [4] for assigning NMR relaxation time distributions in foods and food ingredients. *Sample-centered methods* include systematic variation of water, deuterium, and fat content, as well as controlled adjustments in temperature, and chemical composition. *Multinuclear* (e.g. ^{13}C) *and multidimensional NMR* (e.g. chemical shift, relaxation, diffusion, and imaging) *methods* provide complementary contrast. *Microstructural imaging* methods such as X-ray microtomography and electron microscopy characterize the domains where water, fat, and solids reside, while *simulations* predict relaxation regimes and guide peak identification. Practical examples illustrate the workflow and provide decision rules for interpreting relaxation time distributions. This workflow makes the assignment of relaxation time distributions faster, more reproducible, and less reliant on expert advice.

Keywords:
NMR, relaxation, relaxation time distributions, T1, T2, multidimensional NMR, microstructure, nuclear magnetic resonance



Assignment of the 1H T1 relaxation time distribution for cream cheese at 400 MHz and room temp. The relaxation time distribution of water (a) and fat (b) are separated by employing a 2D T1-resolved chemical shift map. Notice that fat has a small signal component that overlaps that of the water.

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Acknowledgements:
I thank Prof. Thomas Vosegaard and Dr. Kirsten Gade Malmos for valuable discussions.

Films prepared from coacervates of zein: Understanding plasticization through experiments and computer simulations

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The corn-derived protein zein and other prolamins are potentially useful for formulating biobased packaging films since they are quite hydrophopic. We show that a novel way of preparing such films is by using industry standard film applicators to spread out the highly viscous dense coacervate phase that arises after liquid-liquid phase separation in mixed solvents such as water/ethanol. This process can be done at a large scale, drying happens much more quickly than when starting from dilute films, and the films have good mechanical properties. To further reduce the film brittleness we have explored which plasticizers are effective when preparing the films using this new approach. We find that especially intermediate chain-length fatty acids (C8) and short PEG chains (up to PEG2000) are effective. To better understand the molecular conformations of the zein molecules in mixed solvents, including plasticizers, we have started molecular dynamics (MD) studies on a simple minimal model for α-zein: simple repeats of its consensus sequence motif. We show using 5 μs long simulations that equilibration of the model zeins is unusually slow except at the highest ethanol concentrations. Using umbrella sampling we extract potentials of mean force for short pieces of zein-helices as a function of the distance between them. We find that attraction between the helices becomes very strong at higher water content. The picture that arises is of zein molecules as a series of alpha-helical pieces interspersed with prolines where the helices can kink, and with an attraction between the helical pieces that becomes larger as the water content increases. This initial MD work sets the stage for also exploring the molecular mechanisms of plasticization by molecules such as PEG and fatty acids using the same minimal model for zein dissolved in mixed solvents.

Keywords:
Plant-based protein, zein, plasticizer, polyols, molecular dynamics simulations, water-ethanol mixtures, solvents

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A High-Throughput Cost-Effective Platform for Monitoring Viscoelastic Transitions in Hydrocolloids

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Understanding viscosity and elasticity development in hydrocolloid systems often requires monitoring dynamic transitions such as gelation, thickening, or hysteresis across temperature and composition. While conventional rheometry provides detailed characterization, it is slow and sample-intensive when exploring large formulation spaces. Here, we present a low-cost, high-throughput imaging platform that captures viscoelastic transitions by tracking the motion of a metal sphere under controlled oscillatory agitation and temperature cycling.
Sphere trajectories are automatically extracted using deep-learning-based object detection, and sphere mobility is quantified as a proxy for the evolving viscoelastic state of the material. The approach enables parallel measurements across many formulations using simple laboratory equipment and small sample volumes.
The platform was demonstrated across representative soft-matter systems spanning distinct rheological behaviors, including thermoreversible gels, viscous polymer solutions, and ionically cross-linked hydrocolloids. The method resolves temperature-dependent gelation, hysteresis between heating and cooling cycles, viscosity increases without phase transitions, and salt-induced gelation followed by syneresis at high ionic strength. Transition thresholds and temperature-concentration trends show close agreement with oscillatory rheology.
By combining automated image analysis with minimal experimental complexity, this approach provides a scalable route for dynamic, parallel characterization of food colloids. The platform is well suited for data-driven formulation screening, rapid mapping of phase behavior, and integration with machine-learning workflows for accelerated exploration of soft food materials.

Keywords:
High-Throughput Screening, Gelation,Computer Vision, Rheology, Viscoelasticity

References:

Not applicable.

AI-Driven Optimization of Plant-Based Substitutes: Improving Texture and Scalability of the Extrusion Process

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The acceptance of meat substitute products is strongly influenced by quality, with texture and flavor playing particularly important roles. These products are typically manufactured using high-moisture extrusion, where extruder parameters significantly affect textural quality. Scaling from laboratory to industrial extruders is challenging because optimal parameters cannot be linearly extrapolated. As a result, scale-up often depends on trial-and-error, frequently yielding textures that fall short of consumer expectations.
This work demonstrates how to use artificial intelligence (AI) to determine optimal extruder parameters that achieve predefined product quality. Specifically, extruder throughput, screw speed, and the temperatures of the last three zones were optimized using AI methods to reach target mechanical and rheological properties derived from commercially available products.
We show that multi-objective Bayesian optimization can identify parameter combinations that simultaneously improve several quality metrics and approach defined target values based on cutting, amplitude, and tensile tests. Cutting and tensile metrics reached the reference range of commercial products, whereas amplitude-related metrics remained outside this range. In each iteration, the Pareto front gained at least one new Pareto-optimal point; hypervolume increased sharply in the first iteration and then leveled off.
Our results demonstrate that multi-objective Bayesian optimization can be successfully applied in extrusion processes to bring multiple metrics closer to predefined targets and to identify corresponding parameters within a few iterations. This work provides a methodological basis for future studies aimed at improving quality prediction, refining target quality definitions, and enabling more realistic parameter transfer during scale-up. This should accelerate determination of large-extruder settings and help counteract scaling challenges.

Keywords:
Meat Substitutes, Multi-objective Bayesian Optimization, Extrusion, Texture

Understanding emulsion drop breakup using high speed imaging and convolutional neural network classification

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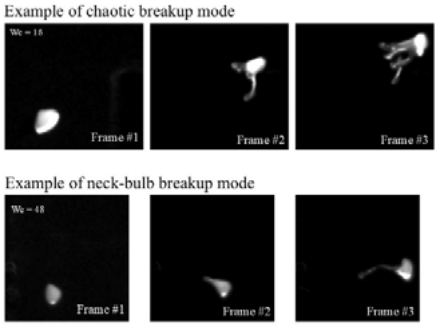
Many foods are emulsions. At an industrial scale, emulsion foods are created and processed using high-energy emulsification processes such as high-pressure homogenizers. A detailed understanding of how emulsions are formed in these devices – and the intricate interplay of hydrodynamic stress and interfacial colloidal chemistry – is essential for creating food emulsions with finely tuned properties at sustainable energy cost.
Whereas homogenizers have been applied industrially for over a century, it is only recently that a more fundamental understanding has emerged. These advances mainly arose from high-speed imaging of single drop breakup. Several studies have revealed that drops break mainly due to turbulent interactions downstream of the narrow gap formed between forcer and seat. Previous studies have also reported on breakup probabilities, breakup times and the effect of interfacial rheology [1,2].
The high-speed imaging experiments undertaken in this study suggest that drop breakup in homogenizers can go via fundamentally different modes (see figure). In the present study, a convolutional neural network (CNN) was developed to study this quantitatively. Together with a drop identification algorithm and a breakup detection algorithm, the CNN allows us to study breakup modes across different operating conditions and device geometries. The poster reports on this novel methodology to combine high-speed imaging and machine learning to study emulsion drop breakup, and on experimental findings.

Keywords:
Emulsification, turbulent drop breakup, convolutional neural network, image analysis



Two examples of drops breaking in two different breakup modes

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Acknowledgements:
AH acknowledges funding from the Swedish Research Council (VR-2024–04823).

Dynamic topological, fractal, and textural quantification of acid induced sodium caseinate gels

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To understand the structure-function relationship in colloidal gels it is essential to correlate macroscopic mechanical responses to microscopic observations. Although super-resolution microscopy like Stimulated Emission Depletion microscopy gives a superior spatial resolution, standard image analysis is limited by its intensity-based segmentation. This approach may cause structural characterization to be susceptible to experimental artifacts, such as dye bleaching, uneven illumination, or drift, which compromise the correlation with the viscoelastic response.
This study presents a novel analysis pipeline for sodium caseinate acid gels, integrating Topological Data Analysis (TDA), Multifractal Partition (MFP), Differential Box Counting (DBC), and Local Binary Patterns (LBP). We quantified the gel formation and evolution of the network over time more reliably by shifting focus from signal intensity to spatial connectivity. TDA tracked network formation, from initial casein aggregates to percolation and network rearrangements, through the appearance of topological loops. DBC and MFP measured dynamic fractal roughness and heterogeneity, while LBP captured local textural shifts from random noise to defined edges. These quantitative descriptors strongly correlated with the viscoelastic characteristics of gelation.
The multiscale and topological approach provides a robust, intensity-independent link between microstructure and mechanical response, with the potential to facilitate image-based texture prediction in complex food systems.

Visualization of dried droplets pattern of protein solution by Ellipsometric Contrast Micrographs (ECM) and Imaging Müller Matrix Ellipsometry (IMME)

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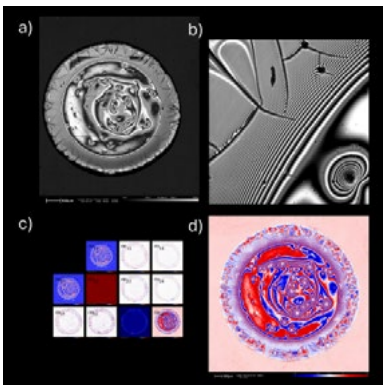
The characterization of patterns in dried biofluid droplets is currently attracting increasing interest, as it is both a simple method and one that yields a high information density caused by rich interplay of evaporation-driven flows, phase segregation, and self-assembly, resulting in patterns that encode significant information [Pal, A., 2025.]. Several authors are combining this method with deep learning approaches. Molina-Courtois et al, (2025) for exanple used Pattern Recognition in Dried Milk Droplets for classifying whole and lactose-free milk and the detection of water adulteration based on deep learning and related methods. Most of these paper are based on conventional microscopy.

Our poster shows two visualization methods, Ellipsometric Contrast Microscopy and Imaging Müller Matrix Ellipsometry, which can highlight specific properties such as anisotropy, layer thickness, or wavelength depending transparency.
To illustrate this, the image shows, firstly, a stitched ellipsometric contrast image of a drop of B-lactoglobulin, as well as a close-up, and secondly, stitched micromaps of 11 elements of the Müller matrix.

The method also enables deep insight into processes such as the drying of protein solutions or mixing effects.

Keywords:
dried droplets pattern, Ellipsometric Contrast Micrographs (ECM), Imaging Müller Matrix Ellipsometry (IMME)



Scheme of the setup at the air/liquid (a) and liquid-liquid interface - with light guides (b)

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Acknowledgements:
DTU- Technical University of Denmark, Food Production Engineering Group,
CAU- Christian Albrechts University, Department of Food Technology

Cavitation Dynamics in High-Pressure Homogenization: From Macroscopic Flow Insights to Process Efficiency

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High-pressure homogenization (HPH) is a key technique in the food industry, particularly in the dairy industry, for creating emulsions [1]. Cavitation—the formation and collapse of vapor bubbles due to extreme pressure drops—plays a central role in determining process efficiency. While some studies report that cavitation enhances droplet breakup and cell lysis, others suggest it may disrupt flow conditions and reduce homogenization performance. [2-4] This work aims to clarify the role of cavitation in HPH and to identify methods for targeted process design and flow analysis.

The work combines experimental and computational approaches. Computational fluid dynamics (CFD) simulations incorporating cavitation models (e.g., Rayleigh-Plesset, Zwart-Gerber-Belamri) were used to map pressure fields, stresses, and cavitation zones across different orifice geometries. Process parameters, including pressure, flow rate, and temperature, were systematically varied. Simulations were validated using experimental data: shadow-graphic images were employed to map the extent of cavitation and various regimes. Droplet size distributions and the protein yield after cell lysis of yeast cells serve as model parameters to evaluate the macroscopic flow behavior in different applications of the HPH process.

The results demonstrate how and to what extent the applied methods can be used to analyze, design, and control industrial HPH processes in terms of cavitation. The study compares the advantages and limitations of each approach and discusses the key challenges associated with their implementation. The framework proves to be a powerful tool for assessing cavitation intensity and its impact on process efficiency, while providing a deeper understanding of the cavitation-driven dynamics that govern droplet breakup and cell disruption.

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Inhibition of Staphylococcus aureus and Listeria monocytogenes in pasteurized white cheese using organic acids and thyme essential oil

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Objectives: This study aimed to investigate the antimicrobial activity of acetic acid (AA), gallic acid (GA) and carvacrol against *Staphylococcus aureus* and *L. monocytogenes* in pasteurized white cheese. Additionally, the effect of the different antimicrobial treatments on the total mesophilic bacterial count (TMC), yeast and mold counts and the impact of the treatments on the physicochemical properties and sensory characteristics of the cheese were evaluated.
Materials and Methods: A cocktail of five *L. monocytogenes* strains and three strains of *Staph. aureus,* were inoculated to reach up ~5 log $_{10}$ CFU/g in brined white cheese (BWC) treated with different concentrations of AA (0.125, 0.25, 0.50 ml/100ml), GA (0.5, 1.0, and 1.5 g/100 ml of brine), and carvacrol (0.1, 0.2, and 0.3 g/l). Thereafter, all treated stored for 30 days at 4, 10, or 24°C. The counts of *L. monocytogenes, Staph. aureus,* TMC, and yeast and mold counts were investigated. Also, pH, salt content, a $_w$ and sensory characteristics of treated BWC were also evaluated.
Results: Using AA against *Staph. aureus* resulted in a bacteriostatic effect during the entire storage period at 4°C and it resulted in *ca.* 0.6-1.0 log lower compared to the control by the end of the 30 d storage time. On the other hand, using GA at 1.0 g/100 ml resulted in a complete elimination of *Staph. aureus* from day 15 and till the end of storage time at 4°C. Also, the combination of AA (0.25%) and GA (1.0%) was also effective in eradicating all inoculated *Staph. aureus* . In comparison, AA was more effective at higher storage temperatures, which resulted in approximately 2-2.3 log reductions compared to the control by the end of storage time at 10 and 24°C, respectively. Also, GA at the level of 1.0% resulted in a complete elimination of *Staph. aureus* before the end of storage time. On the other hand, the different concentrations of AA resulted in *ca.* 0.7-1.4 log reduction in *L. monocytogenes* in BWC compared to the control after 30 d of storage at 4°C and the effect increased with increasing AA concentration. However, at 10 and 24°C, AA was less effective . Caracole was the most effective agent in reducing the counts for *Staph. aureus* at all storage temperatures and the counts were >3.0 logs lower compared to the control at the end of storage time. However, carvacrol was less effective against *L. monocytogenes* , especially at lower storage temperatures. Nonetheless, it imparted significantly lower ($p< 0.05$) counts compared to the control. Generally, AA and carvacrol did not adversely affect the organoleptic properties of the BWC and the product was acceptable compared to the control.
Conclusion: In the current study it was possible to preserve BWC quality and safety using organic acids and essential oils. The addition of AA, GA and carvacrol has the potential to reduce the risk of *Staphylococcus aureus* and *L. monocytogenes* contamination in BWC and extend its shelf life.

Grass pea (Lathyrus sativus L.) flour: physicochemical and functional properties as affected by hydrothermal pre-treatments

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Grass pea (Lathyrus sativus L.) flour, derived from an underutilized and climate-resilient legume, is a promising ingredient for sustainable food formulations; however, its technological potential remains largely unexplored. The present work was thus undertaken to investigate how moisture-controlled hydrothermal treatments, carried out at 100°C for 30 minutes under four moisture conditions (9, 30, 50, and 70% w/w), can affect grass pea flours physical-chemical properties and functionality. Differential scanning calorimetry showed progressive modifications of starch thermal transitions with increasing treatment moisture, including shifts in gelatinization temperatures and a reduction in enthalpy, suggesting partial structural disruption and reorganization. Changes in the starch–lipid complexation index indicated the occurrence of amylose–lipid interactions. Water absorption index and oil absorption capacity revealed systematic alterations in hydration behavior, consistent with structural rearrangements within the flour matrix. Particle size distribution and color analysis further supported moisture-induced modifications of the flours. The rheological behavior of standardized gels prepared from treated flours demonstrated significant differences in viscoelastic response, with frequency sweep measurements indicating changes in network strength as a function of treatment moisture. Hydrothermal processing at controlled hydration levels modulates the structural organization of grass pea flour components, leading to distinct hydration and viscoelastic behaviors. These findings provide useful information for tailoring grass pea flour functionality through moisture-controlled thermal treatments for structured food systems.

Acknowledgements:
This work has been funded by the European Union - NextGenerationEU, Mission 4, Component 1, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY - CUP: C43C22000380007.

Parametrization of Stribeck curves to link tribological descriptors with sensory perception in EVOO–pea protein emulsions with a multivariate statistical approach

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Understanding how structural, flow and lubrication behavior relates to sensory perception remains a major challenge in food colloid science, particularly when dealing with complex multiphasic systems. In this study, oil-in-water emulsions based on extra virgin olive oil (EVOO) and stabilized by pea proteins were systematically formulated using a central composite design varying phase volume and oil composition. Stribeck curves were parametrized using a normalized Weibull-model, enabling extraction of global descriptors of lubrication behavior across the different regimes (alpha, beta, μ_0, μ_e). These model-derived parameters were then integrated with structural (droplet size distribution, ζ-potential) and rheological (consistency index, flow behavior index, yield stress) data. Partial least squares (PLS) regression was applied to establish quantitative relationships between physical descriptors and sensory attributes evaluated by a trained panel (creaminess, mouth-coating, smoothness, thickness, fattiness, bitterness, pungency, astringency, oiliness). The tribological parameters significantly contributed to the predictive ability of the multivariate model applied, especially for lubrication-driven perceptions such as creaminess, smoothness and mouth-coating. These results demonstrate that integrating tribological parametrization with structural and rheological descriptors can represent a valuable tool for the design of complex emulsified foods with tailored lubrication properties.

Acknowledgements:
This work has been funded by the European Union - NextGenerationEU, Mission 4, Component 1, under the Italian Ministry of University and Research (MUR) National Innovation Ecosystem grant ECS00000041 - VITALITY - CUP: C43C22000380007.

Multiscale Characterization of Acid-Induced Milk Gels: Influence of Fish Gelatin on Network Formation Dynamics and Mechanical Properties

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This study investigated the physicochemical and structural characteristics of acid-induced milk gels formulated with and without warm-water fish gelatin (0.5%, w/w) during glucono-δ-lactone–mediated acidification (2%, w/w), followed by controlled cooling, annealing, and refrigerated storage (up to 7 days at 4 °C). A comprehensive multiscale analysis was performed combining small- and large-amplitude oscillatory shear rheology and texture analysis at the macroscopic level, passive particle tracking microrheology at the microscopic level, and time-resolved small-angle X-ray scattering (SAXS) at the nanoscopic level.

Gelatin incorporation induced a temperature-dependent two-stage effect on gelation and network development at the macroscopic level, resulting in delayed yielding under large deformation. Stress relaxation analysis indicated that gelatin promoted slower and more uniformly distributed relaxation processes, whereas control gels exhibited more rapid stress decay and a broader relaxation time spectrum. SAXS measurements suggested that gelatin contributed to a comparatively more homogeneous nanostructural organization, while control systems underwent progressive fusion and rearrangement of heterogeneous protein clusters into larger aggregates during storage. Microrheological assessment further revealed enhanced spatial heterogeneity and increased pore-scale variability in gels without gelatin at extended storage, in contrast to the comparatively stabilized microstructure of gelatin-containing systems.

Collectively, these results demonstrate that even at sub-gelling concentrations, fish gelatin significantly modulates the temporal development, structural organization, and mechanical response of acid-induced milk protein networks across multiple length scales, enhancing structural stability while reducing micro- and nanoscopic heterogeneity.

Keywords:
Acid milk gel, fish gelatin, gelation, rheology, texture, compression, relaxation, LAOS, particle tracking, SAXS

Phospholipid and Fatty Acid Profiles of Vegetables and Seaweeds: Implications for Food Colloid Systems

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Phospholipids and fatty acids play crucial roles in determining the structural, interfacial, and functional properties of food colloids; however, compositional information for plant-based foods remains limited. This study analyzed the phospholipid profiles and fatty acid compositions of 18 vegetables and 10 seaweeds to provide fundamental insights into plant-derived lipids relevant to food colloid systems.

Phospholipids were quantified using HPLC–ELSD, which showed excellent specificity and linearity ($R^2 \geq 0.9994$) for phosphatidylethanolamine (PE), phosphatidylcholine (PC), phosphatidylinositol (PI), and lysophosphatidylcholine (LPC), with low limits of detection and quantification (LOD: 0.20–0.50 μg/mL; LOQ: 0.58–1.20 μg/mL). The major PLs identified in vegetables and seaweeds were PC, PE, and PI, with LPC detected in selected samples. In vegetables, total PL content ranged from 35.6 to 449.1 mg/100 g DW, with cauliflower, broccoli, and yeolmu exhibiting the highest levels. PC was predominant (15.3–216.8 mg/100 g DW), followed by PE (1.0–106.2 mg/100 g DW) and PI (6.6–126.2 mg/100 g DW). In seaweeds, total PL content ranged from 1.86 to 191.8 mg/100 g DW, with sea mustard, sea string, and mojaban rich in PC (8.6–131.6 mg/100 g DW) and PI (2.2–60.3 mg/100 g DW); PE (0.49–42.4 mg/100 g DW) was characteristic of several brown species.

In vegetables, the dominant fatty acids were palmitic, linoleic, and α linolenic acids, with polyunsaturated fatty acids reaching up to 7.5 g/100 g DW. Seaweeds contained palmitic acid as a common major fatty acid, but showed phylum specific patterns: α linolenic acid was prominent in green algae, arachidonic acid in brown algae, and eicosapentaenoic acid (EPA) in red algae, while maesaengi uniquely contained docosahexaenoic acid (DHA).

Overall, this study provides a comprehensive lipid compositional dataset for vegetables and seaweeds and highlights their potential as functional ingredients in food colloid systems, particularly for plant-based food formulations.

Keywords:
phospholipid, fatty acid, vegetables, seaweeds

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Acknowledgements:
This research was funded by Project No. RS-2022-RD010069 under the Rural Development Administration (RDA, Republic of Korea).

Diffusion of active pepsin in dairy emulsions textured by carrageenans

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Density, texture and microstructure of foods can be critical for particle fragmentation and hydrolysis of macronutrients, affecting the digestive enzyme behaviour (Dekkers et al., 2016). It has been shown that the relationship between the texture of food matrix and pepsin diffusion affect the functional and nutritional value of protein consumption (Somaratne et al., 2020; Zhao et al., 2020). Rakhshi et al. (2022) has proposed that pepsin diffusion would be related to the density of the protein network in complex food matrix. For dairy product, Thevenot et al. (2017) reported that the diffusion coefficients of FITC-pepsin were reduced as the casein concentration of the dairy gels increased. However, the two last studies were performed using FITC labelled enzyme, leading to the inactivation of the enzyme.
In this study, for the first time to our knowledge, a labelling method allowing to maintain the pepsin activity was developped. The activity of the enzyme was measured using hemoglobin as substrate. Rheological behaviours of WPI gels containing native and labelled pepsin, at pH 3 and 37°C, was compared, showing close results which allows using the labelled pepsin in diffusion experiments.
Therefore, the diffusion of pepsin was monitored in more complex systems. Emulsions were formed using 30% of anhydrous milk fat, whey proteins, and k-carrageenan in presence of potassium ions was used to modify the texture. Rheological behaviour and granulometry of the droplets of the emulsions containing pepsin were monitored during 3 hours. In parrallel, FRAP experiments, using CLSM, were performed to monitor the diffusion of the labelled active pepsin in the different systems. The results obtained showed that pepsin diffusion is strongly affected by the texture of the system, evidencing a strong decrease when the gel strength of the matrix increased. Furthermore, the diffusion coefficients of the active labelled pepsin were much lower than those reported in the litterature with inactive labelled enzyme. The same behaviour was also obtained with labelled active Pectin Methyl Esterase in pectin gels (Videcoq et al., 2013).
The results are discussed with regards to the specificity and reactivity of the pepsin in gelled emulsions.

Keywords:
Gelled emulsion; Mechanical properties; Pepsin Diffusion; FRAP

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Comparative Analysis of Spirulina Protein Fractions Using Colloid Metrics and Soft Tribology

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Spirulina protein (*Arthrospira plantensis)* is being used extensively in food formulations, however at very low quantities because its oral performance and sensory properties are poorly understood and are often treated as a 'single protein problem'. In this research, spirulina protein was seperated into Osborne fractions (albumin, globulin, prolamin and glutelins), freeze-dried and re-constituted under controlled hydration conditions. The fractions and the co-extracted non-protein components were identied and confirmed with SDS-PAGE and Circular Dichroism (CD). The colloidal properties were tested across oral-relevant conditions of pH and ionic strength by measuring solubility, aggregate size distributions, and zeta potential, alongside bulk flow curves to account for viscosity effects.
Oral lubrication was quantified by soft-tribology (PDMS-PDMS) to generate Stribeck curves in buffer and artificial saliva, with salivary pellicle pre-conditioning to probe boundary-film effects. Among the different fractions, albumin-rich fractions showed the highest solubility at near-neutral pH and formed finer dispersions, giving lower boundary friction and an earlier transition into mixed lubrication compared with whole extract. Overall, the results demonstrate that fraction-dependent colloidal state governs oral lubrication regimes, providing a mechanistic route to design spirulina protein ingredients with targeted oral performance.

Determination of Apparent HLB-Equivalent Value of Defatted Brown Rice Protein

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Brown rice protein (BRP) has been studied for its emulsifying properties; however, quantitative characterization of its interfacial properties remains limited. In this study, defatted BRP (dBRP) was prepared, and its composition, solubility, and apparent HLB-equivalent value in a rice bran oil (RBO)/water system were evaluated. Proximate analysis indicated that defatting reduced crude fat content from 22.7% to 5.5%, while increasing crude protein content from 68.0% to 88.9%. Over a pH range of 2-12, dBRP exhibited significantly higher protein solubility than non-defatted BRP. Interfacial tension at the RBO/water interface was measured at 25 °C using the Wilhelmy plate method. Standard surfactant mixtures (0.1%, w/w) with HLB values ranging from 4.3 to 14.0 were used to construct an interfacial tension-HLB regression curve. The interfacial tension of dBRP (0.1%) was determined to be 9.16 ± 0.02 mN/m. Interpolation of this value using a regression model yielded an apparent HLB-equivalent value of approximately 10.2. This value suggests that dBRP exhibits amphiphilic characteristics consistent with oil-in-water emulsification in the RBO/water system. However, further analyses, such as determination of the required HLB, are necessary for a more comprehensive characterization of its interfacial behavior.

Keywords:
defatted brown rice protein, apparent HLB-equivalent value, interfacial tension, solubility

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Development of Sericin-Based Bigel as a Shortening Replacer for Saturated Fat Reduction in Cookies

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Growing interest in fat replacement strategies has led to increasing research on structured fat systems such as bigels. This study developed a sericin-based bigel as a potential fat replacer by combining a hydrogel prepared from sericin (a byproduct of silkworm cocoons) with a glycerol monostearate (GMS) oleogel, and evaluated its applicability as a shortening substitute in cookies. Response surface methodology(RSM) was used to determine the optimal bigel formulation (hydrogel 30 g : oleogel 20 g). The optimized bigel was incorporated into cookies at varying substitution levels, and the resulting products were analyzed for physical properties, textural characteristics, and fatty acid composition. Bigel incorporation did not significantly affect cookie weight, while thickness increased and spread ratio decreased with increasing substitution levels due to the enhanced water-binding capacity of sericin. Texture analysis showed no significant differences in hardness up to 75% bigel replacement, indicating that acceptable textural quality was maintained. Fatty acid analysis demonstrated a pronounced improvement in lipid profile with increasing bigel substitution. Saturated fatty acids (SFA) decreased markedly from 86.86% in the control cookies to 23.46% at the highest substitution level, while monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) increased to 31.10% and 45.44%, respectively. These findings indicate that sericin-based bigels can effectively replace commercial shortening while improving the nutritional quality of bakery products.

Keywords:
sericin-based bigel, fat replacement, response surface methodology, fatty acid composition

Volatile Compound Profiling and Consumer Preference Analysis of Citrus Pomace-Incorporated Gel-Based Yanggaeng

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Citrus pomace, a byproduct of citrus processing is gaining recognition as a sustainable food resource due to its rich content of volatile and functional compounds. This study comprehensively analyzed the relationship between changes in volatile composition changes and consumer preferences by incorporating citrus pomace into gel-based yanggaeng at concentrations ranging from 1% to 5%. Headspace solid-phase microextraction-gas chromatography-mass spectrometry (HS-SPME–GC–MS) analysis identified 33 volatile compounds. The content of terpenes, including D-limonene, α-farnesene, and p-cymene, significantly increased with higher citrus pomace concentrations ($p < 0.05$). Correspondingly, the intensity of citrus aroma also showed a concentration-dependent enhancement. Consumer preference evaluations revealed that the 1% addition group exhibited the highest overall liking ($p < 0.05$). A trend was observed where the balance between aroma intensity and preference varied depending on the level of citrus pomace addition. Pearson correlation analysis revealed significant positive correlations between terpene compounds and citrus aroma intensity, while consumer preference closely associated with taste and sweetness attributes. These findings demonstrate that citrus pomace addition can effectively modulate the aroma profile within a gel food matrix, underscoring the importance of optimizing concentrations to align with consumer preferences. This study provides empirical evidence for the high-value utilization of citrus by-products and contributes to the development of flavor modulation strategies in colloidal food matrices.

Physical and oxidative stability of plant protein-based aroma emulsions

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Gum arabic is widely used as an emulsifier in soft drinks and aroma emulsions. In light of increasing consumer health awareness, growing demand for clean-label products, and the general shift toward plant-based ingredients, plant proteins are gaining attention as potential alternative emulsifiers. The aim of this study was to systematically evaluate plant proteins for application in aroma emulsions.
A major challenge when using proteins as emulsifiers in aroma emulsions is their high interfacial reactivity. Partial unfolding at the oil-water interface may promote interactions with reactive aroma compounds, potentially leading to off-flavour formation via reactions with free amino groups. To minimize such effects, β-conglycinin from soy and napin from rapeseed were selected due to their molecular structures, which limit extensive unfolding at the interface. Soy and rapeseed protein isolates were analysed as reference samples, and gum arabic was included as an industrial benchmark. Since oxidative stability requires sufficient physical stability, the emulsifying performance of these samples was assessed based on droplet size distribution and visual evaluation of destabilization phenomena such as creaming. Interfacial adsorption behaviour and viscoelastic properties at the orange oil terpene-water interface were characterized using shear and dilatational interfacial rheology. Oxidative stability was determined using accelerated aging via the OXITEST method.
Results show that soy proteins (isolate and β-conglycinin) exhibited high and long-term physical stability, whereas rapeseed protein-based emulsions showed limited stability, reflected in larger initial droplet sizes. These differences were protein- and fraction-specific and could be attributed to distinct adsorption and interfacial film formation mechanisms. Soy protein isolate and β-conglycinin demonstrated efficient interfacial adsorption and the formation of viscoelastic, shear-resistant films. In contrast, napin formed less stable interfacial layers due to restricted unfolding, limited intermolecular networking and lower ζ-potential, promoting droplet aggregation and creaming over time. With regard to oxidative stability, selected plant proteins demonstrated suitability depending on their interfacial behaviour, achieving performance comparable to that of the gum arabic reference. Overall, soy proteins in particular exhibited functionality equivalent to gum arabic in aroma emulsion applications.

Impact of the extraction method on the functional properties of lentil starch-rich fractions

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Introduction: Legumes represent a sustainable and highly nutritious plant-based resource, characterised by a relatively low environmental footprint during primary production. Over the past decade, legume protein isolates have been widely incorporated into a broad range of food applications. In contrast, considerably less attention has been paid to pulse starches, despite being the major constituent of legumes, accounting for approximately 35-60% of their composition. In particular, knowledge regarding their extraction processes, structural modification, and functional performance in food systems remains limited [1]. In this context, this study investigates the impact of a mild extraction approach (dry fractioning) on the functional properties of lentil starches.

Materials and methods : Two lentil varieties, Castilian (LP) and Pardina (LP), were purchased from local retailers in Valencia, Spain. Starch-rich fractions were obtained by sieve-based dry fractionation. Samples extracted using the conventional wet method (LCc and LPc) were used as controls. Proximate composition, FTIR spectroscopy and rheological properties of all samples were determined following the methodologies described in references [2, 3].

Results: The starch-rich fractions obtained by dry fractionation contained 50.64±2.04 and 49.41±1.44 g/100 g DB of starch for LC and LP, respectively. In contrast, the control samples (LCc and LPc) showed significantly higher starch contents, reaching 91.24±1.68 and 91.6±2.0 g/100 g DB, respectively. The less purified fractions were characterized by higher levels of protein, ash, and total phenolic compounds, which may confer enhanced functional and nutritional value. The extraction method also influenced the structural characteristics of the samples. FTIR spectral analysis revealed that the LP and LC fractions exhibited absorbance peaks associated with amid I and amid II vibrations, indicating the presence of residual proteins that may affect the colloidal behaviour of the starch systems. Rheological characterization of starch suspensions revealed less that LCc and LPc samples exhibited lower stability under shear stress, with thixotropic areas 4.3 and 7.9-fold higher, respectively, compared to LC and LP. Overall, these results suggest that lentil starch-rich fractions obtained through a milder and more sustainable dry fractionation process may serve as functional ingredients with distinct and potentially advantageous physicochemical properties.

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Acknowledgements:

This work was supported by the project PID2023-146123OB-C32 funded by MICIU/AEI/10.13039/501100011033 and by ERDF, EU. Also, it has received funding through the MSCA4Ukraine project, which is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, the European Research Executive Agency or the MSCA4Ukraine Consortium. Neither the European Union nor the European Research Executive Agency, nor the MSCA4Ukraine Consortium as a whole nor any individual member institutions of the MSCA4Ukraine Consortium can be held responsible for them. And authors are grateful for financial support from doctoral Grant (PAID-01-24) from the Universitat Politècnica de València).

Next-Generation Bigel Beads: A Novel Approach for Stabilizing and Delivering Natural Carotenoids

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Bigels are innovative soft-solid materials that have attracted increasing attention in the food industry due to their structural versatility and functional potential. As hybrid systems integrating hydrogel and oleogel characteristics, bigels represent promising platforms for the encapsulation and controlled delivery of bioactive compounds [1]. Pitanga (*Eugenia uniflora*) carotenoids, naturally characterized by their intense orange coloration, have emerged as attractive alternatives to synthetic food colorants while also offering additional functional benefits [2]. However, these compounds are highly susceptible to degradation induced by light, oxygen, and temperature, limiting their direct incorporation into food matrices and underscoring the need for effective stabilization strategies. In this study, novel bigel microbeads were developed using a hydrogel (HG) phase composed of alginate/κ-carrageenan/pea protein isolate combined with a glyceryl monostearate (GMS)-based oleogel (OG) phase. The structural attributes of the systems were tailored by varying the HG:OG ratio (80:20 and 60:40) in order to modulate microstructure, stability, and release performance. The protective effect of the beads on carotenoid stability was assessed through scanning electron microscopy (SEM), CIELab color analysis, and controlled release assays. The microbeads exhibited good sphericity and physical stability, with formulations containing higher oleogel content showing reduced shrinkage rates. Protein incorporation provided additional structural reinforcement, enhancing network cohesion compared to protein-free systems. SEM analysis further demonstrated that the HG:OG ratio significantly influenced microstructural organization and surface characteristics. Fourier Transform Infrared Spectroscopy (FTIR) analysis confirmed the structural integrity of the individual components, with no detectable formation of new functional groups or covalent interactions between the hydrogel and oleogel phases. The 60:40 formulation displayed a higher magnitude zeta potential (−52.56 mV) compared to the 80:20 system (−25.83 mV). Protein incorporation tended to reduce surface charge magnitude, whereas increasing the oleogel fraction enhanced electrostatic stabilization. The bead-based formulation effectively preserved carotenoids during storage at both 4 °C and 22 °C. The findings demonstrated that color stability and release behavior were strongly influenced by the HG:OG ratio. Specific oleogel fractions were identified as optimal for enhancing carotenoid retention while modulating release kinetics. Overall, emulsion gel composition played a decisive role in determining the interfacial and microstructural properties of the beads, thereby governing compound stability and delivery performance. Collectively, these results establish a scientific framework and provide new insights for the engineering of advanced bigel-based encapsulation systems, fostering innovative approaches for the stabilization and controlled release of emerging bioactive ingredients.

Keywords:
Natural carotenoids, Bigel beads, Controlled release, Color stability, Bioactive delivery

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Acknowledgements:
V.V. De Rosso acknowledges the National Council for Scientific and Technological Development (CNPq) for their financial support (fellowship 315378/2021-2) and CAPES - PROEX.

Structural Design of Hydrogel and Bigel Beads for Improved Phycocyanin Stability and Release Control

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Hydrogels and bigels have attracted considerable attention as structured systems for the stabilization and delivery of sensitive bioactive compounds. While hydrogels provide hydrated polymeric networks, bigels integrate hydrogel and oleogel phases into hybrid matrices with tunable structural properties. Phycocyanin, a hydrophilic natural pigment–protein complex with recognized functional potential, is highly susceptible to environmental degradation, which limits its practical application [1]. In this context, the present study aimed to develop hydrogel- and bigel-based beads as encapsulation systems to enhance the stability and functional performance of phycocyanin from *Limnospira platensis*. The hydrogel (HG) phase, composed of alginate and κ-carrageenan, was employed as the polymeric matrix and combined with a glyceryl monostearate (GMS)-based oleogel (OG) phase to produce bigel beads at an HG:OG ratio of 80:20. Phycocyanin was incorporated into the hydrogel fraction at 1% (w/w). In both systems, ionic crosslinking was induced by Ca^{2+} ions, promoting electrostatic interactions between alginate carboxylate groups and stabilizing the three-dimensional network. The beads exhibited good sphericity and physical stability. Fourier Transform Infrared Spectroscopy (FTIR) analysis showed no emergence of new absorption bands or significant peak shifts, confirming the absence of covalent interactions between phases and indicating that structural organization was predominantly governed by non-covalent interactions. Scanning electron microscopy (SEM) revealed distinct microstructural differences between hydrogel and bigel beads, demonstrating that oleogel incorporation modified particle morphology and surface characteristics. Encapsulation efficiency exceeded 60%, and the oleogel fraction in bigel beads contributed to compound retention, likely by acting as an additional barrier against diffusion and degradation. Hydrogel beads displayed a higher magnitude zeta potential (−64.31 mV) compared to bigel beads (−48.22 mV); however, both systems exhibited strong negative surface charge, indicating adequate electrostatic stability. Swelling assays showed greater water uptake in hydrogel beads, reflecting their predominantly hydrophilic nature. CIELab color analysis demonstrated significant differences in L^*, a^*, b^*, and ΔE^* values between systems. Hydrogel beads exhibited more intense blue coloration, whereas bigel beads showed slightly lower intensity but improved chromatic stability during storage. Release behavior varied according to gel type, confirming that matrix composition played a key role in modulating compound diffusion. Altogether, these findings highlight the potential of hydrogel and bigel bead systems as promising and tunable platforms for the stabilization and controlled delivery of phycocyanin in functional applications.

Keywords:
Phycocyanin, Hydrogel beads, Bigel beads, Controlled release; Color stability; Bioactive delivery.

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Engineering Freeze-Dried Bigel Matrices for the Encapsulation and Stabilization of Natural Chlorophylls

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Encapsulation has been widely employed to enhance the stability of bioactive compounds through the formation of protective barriers. In this context, freeze-drying stands out as an efficient method when combined with structured wall materials. Bigels, hybrid systems resulting from the integration of hydrogel and oleogel phases, can act as such structural matrices, enabling the protection and delivery of labile molecules. The main objective of this study was to evaluate the capacity of bigels as carrier systems and freeze-drying as an encapsulation method for natural chlorophylls. For this purpose, edible ingredients were used, and different bigel formulations were developed, containing an oleogel (OG) composed of sunflower oil and glycerol monostearate, and two distinct hydrogels (HG), agar and κ-carrageenan, both supplemented with pea protein isolate. The bigels were formulated at an HG/OG ratio of 80:20. *Scenedesmus obliquus* extracts were incorporated as a source of natural chlorophylls at a concentration of 10 mg/100 g in the oleogel fraction. For all bigels, rheological analysis demonstrated predominantly solid-like behavior (G′ > G″) and pronounced pseudoplastic characteristics, with evident shear-thinning properties. The average mass yield after freeze-drying was approximately 27%, with no significant differences among the evaluated bigels. Scanning electron microscopy (SEM) revealed that the type of polysaccharide significantly influenced the morphological features and surface properties of the freeze-dried powders. A leaching test was performed on fresh bigels, and in both systems, oil and water phases were detected in the released liquid. However, more than 98% of the leached fraction originated from the aqueous phase, regardless of the polysaccharide used in the formulation. Chlorophyll incorporation increased liquid loss in κ-carrageenan-based bigels, while reducing it in agar-based systems. After freeze-drying, a substantial reduction in leached liquid was observed, with the released fraction predominantly composed of the oil phase. Agar-based bigels exhibited lower liquid loss (1.5%) compared to κ-carrageenan systems (8%). Color stability was monitored using CIELab parameters over 21 days under both ambient (22 °C) and refrigerated (4 °C) storage conditions. Freeze-drying contributed to improved chromatic stability throughout storage in both systems. Notably, freeze-dried agar-based bigels displayed a more intense green coloration and better retention of this hue over time, regardless of storage conditions. These findings suggest that bigels combined with freeze-drying may represent a promising strategy for the enhanced encapsulation of natural pigments, contributing to the preservation of their functional and color properties.

Keywords:
Bigels, Encapsulation, Chlorophyll, Freeze drying, Color stability.

Acknowledgements:
This work was supported by the São Paulo Research Foundation (FAPESP) [grant numbers 2021/13567-5].

Bigel Beads as Advanced Platforms for Chlorophyll Stabilization and Controlled Release

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In recent years, bigels have emerged as an innovative approach in the development of gelled systems for food applications. These semi-solid structures exhibit biphasic organization and high functional versatility, being widely explored as platforms for the delivery and controlled release of bioactive compounds. Within this context, chlorophylls have gained increasing technological interest due to their distinctive structural features and chemical reactivity, which enhance their potential application as functional ingredients. Considering these aspects, the main objective of this study was to develop novel food-grade functional bigel beads for the encapsulation of natural chlorophylls. κ-Carrageenan and agar were employed as structural-modifying polysaccharides to produce alginate-based emulsion gel microbeads containing a monoglyceride oleogel phase. Functional extracts obtained from the cyanobacterium *Limnospira platensis* were used as a source of natural chlorophylls. The emulsion gels were prepared at a hydrogel/oleogel (HG/OG) ratio of 80:20. Polysaccharide incorporation generally increased microbead size, while agar reduced the shrinkage rate. Scanning electron microscopy (SEM) revealed that the type of polysaccharide significantly influenced the morphological characteristics and surface properties of the beads. Release assays demonstrated that the structural architecture of the microbeads played a determinant role in modulating compound release. Rheological characterization showed that interactions between the hydrogel and oleogel phases were modulated by the type of polysaccharide, resulting in differences in viscoelastic moduli. Bigels containing κ-carrageenan exhibited higher apparent viscosity and greater G' values, indicating enhanced elastic dominance and a more structured three-dimensional network. Fourier Transform Infrared Spectroscopy (FTIR) analysis indicated the absence of significant chemical interactions between the alginate hydrogel and the monoglyceride oleogel, as well as no evidence of covalent bond formation between alginate and the additional polysaccharides. Color stability was monitored using the CIELab system over 21 days to evaluate the influence of bead composition on chromatic parameters. The stability of chlorophyll-enriched systems was dependent on the type of polysaccharide used in the formulation. Although variations in L^*, a^*, and b^* values were observed among samples, ΔE^* values generally indicated low perceptibility of color differences throughout storage. Polysaccharide incorporation significantly influenced the physicochemical properties of alginate microbeads, effectively modulating both the release profile and stability of the bioactive compounds. These findings establish a scientific basis for the engineering of natural polymer-based bigel beads and expand the prospects for the development of advanced controlled-release systems.

Keywords:
Natural chlorophylls, Bigel beads, Controlled release, Color stability, Bioactive delivery

Acknowledgements:
This work was supported by the São Paulo Research Foundation (FAPESP) [grant numbers 2021/13567-5].

Machine-Learning-Guided Robotic Layer-by-Layer Assembly of Biopolymer Multilayers with Tunable Mechanical Properties

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Background
Layer-by-layer (LbL) assembly enables precise control of biopolymer multilayer architecture and, in principle, their mechanical response. However, mechanical tuning is typically achieved by changing solution conditions, which masks the isolated effects of deposition sequence and terminal-layer history at fixed composition. Robotic high-throughput LbL and emerging ML models create an opportunity to systematically map and predict architecture–property relationships[1-3]. Here, we aim to establish and model sequence–mechanics relationships in fixed-composition Alg/Chi/Gel/Pec (25% each) 100-layer films using robotic DoE fabrication and interpretable ML to enable architecture-only mechanical tuning.
Materials and methods
We developed a fully automated robotic dip-coating workflow to fabricate 100-layer biopolymer films with fixed global composition (Alg/Chi/Gel/Pec, 25% each), using deposition sequence as the sole design variable. The library comprised binary reference films (Alg/Chi, Alg/Gel, Pec/Chi, Pec/Gel) and 32 quaternary architectures (16 forward + 16 reverse) chosen to maximize diversity in sequence space, while all processing parameters were kept constant. Films were characterized by ATR-FTIR, SAXS/WAXS, DSC, TGA, SEM, thickness mapping, and tensile-mode DMA (E, E′, E″, tan δ, UTS, ε_break). DoE statistics (main effects/interactions, ANOVA) and non-linear ML regression with sequence-encoded descriptors were used to model and interpret sequence–property relationships.
Results
DoE analysis indicates that, even at constant global composition and constant assembly conditions, deposition sequence measurably modulates thickness uniformity, stiffness, and damping. Forward/reverse pairing reveals directionality effects, consistent with the role of early-layer "nucleation" and terminal-layer history in shaping interfacial organization across the multilayer stack. Structural readouts (FTIR; SAXS/WAXS; SEM) support the interpretation that sequence-dependent electrostatic/hydrogen-bonding networks and nanoscale organization are coupled to thermo-mechanical response. ML models trained on the DoE dataset provide accurate, interpretable mappings from sequence descriptors to mechanical targets and highlight a compact set of dominant architectural predictors, enabling prioritization of promising sequences for targeted mechanical profiles.
Conclusions
This work establishes an integrated platform combining robotic LbL fabrication, DoE planning, and ML-assisted modeling to isolate architecture-driven control of mechanical properties in four-biopolymer multilayers at fixed composition. The framework supports data-efficient exploration of sequence space, extraction of transferable design rules (including terminal-layer and directionality effects), and provides a basis for multi-objective optimization of mechanical performance without altering solution chemistry or the material set.

Keywords:
layer-by-layer assembly; biopolymer films; mechanical properties; design of experiments; machine learning; robotics

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Acknowledgements:
The European Union has funded this work through the Marie Skłodowska-Curie grant (No 101151044, BIOCOMAT) awarded to S.L.W.

PCA-guided optimization of pectin–chitosan multilayer films for controlled anthocyanin release

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Background: Anthocyanins are bioactive flavonoid pigments with documented antioxidant and anti-inflammatory potential, but their practical use is limited by very low bioavailability (often <1%) and high sensitivity to pH, temperature, oxygen, and light. Layer-by-layer (LbL) assembly enables mild, controllable fabrication of pH-responsive barriers, yet integrated, quantitative structure–property–function correlations across mechanical, thermal, transport, and antioxidant metrics are still scarce [1-4].
Aim: To develop a dual-stabilization anthocyanin delivery platform by combining zein–anthocyanin coacervate nanoparticles with spray-assisted LbL biopolymer films, and to use PCA/Spearman analysis to identify robust film architectures for controlled release.
Materials and Methods: Anthocyanin-loaded zein nanoparticles (ZANPs) were prepared by antisolvent precipitation/coacervation; ZANPs showed colloidal stability with positive ζ-potential favorable for subsequent deposition of anionic polysaccharides. 40-layer spray-LbL films (alginate/pectin/zein/chitosan variants) were fabricated with and without ZANP interlayers, then characterized by SEM/DLS/ATR-FTIR, TGA/DSC, thickness and tensile testing, swelling and in-vitro release at gastrointestinal-relevant pH, and antioxidant assays (ABTS/FRAP); multivariate analysis (PCA + Spearman heatmaps) integrated the dataset across architectures.
Results: Among multilayer films, pectin/chitosan with ZANPs (P/Ch/A) delivered the best overall profile, with EE = 77.0%, elevated antioxidant capacity, and superior mechanical properties. Thermal analysis indicated increased stability for chitosan-containing systems (P/Ch/A, A/Ch/A), consistent with denser interfacial bonding and phenolic–polymer interactions. Release studies showed that uncoated coacervates exhibited a rapid burst (>50% in <30 min at pH 7.4), whereas LbL films shifted transport toward sustained, diffusion-controlled profiles; under intestinal pH, ZANPs reached 78% release at pH 7.4 after 4 h, while LbL films peaked later with moderated maxima, confirming the added diffusion barrier from the multilayer shell.
Conclusions: A core (zein–anthocyanin) + LbL shell strategy enables a mechanically robust, thermally stable, and pH-responsive platform for anthocyanin delivery. PCA-guided integration of structural, mechanical, transport, and antioxidant variables identifies P/Ch/A as the most promising biodegradable architecture for controlled polyphenol release, supporting translation toward biomedical and active-food applications.

Keywords:
layer-by-layer assembly; biopolymer films; anthocyanins; encapsulation efficiency; controlled release; PCA

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Acknowledgements:
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Curd cheese fortified with jujube (Ziziphus jujuba) extract: impact on selected quality parameters

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In recent years, *Ziziphus jujuba* has attracted considerable scientific interest due to its rich content of bioactive compounds, including polyphenols, flavonoids, saponins, and polysaccharides, which exhibit antioxidant, anti-inflammatory, and immunomodulatory properties. Among these constituents, jujube polysaccharides are considered particularly important because of their documented antioxidant, hepatoprotective, and gut microbiota- modulating effects, supporting their potential application in functional food development [1,2,3]. The incorporation of plant-derived extracts into dairy systems has been widely investigated as a technological strategy to enhance functional value while simultaneously modifying physicochemical and rheological properties [4]. Previous studies have demonstrated that the addition of jujube pulp can significantly affect milk coagulation behavior and the microstructure of both acid- and rennet-induced gels, leading to alterations in textural characteristics [5]. Moreover, jujube-enriched cream cheese products have been reported to exhibit changes in composition, texture, and sensory quality [6].
The present study aimed to evaluate the effect of *Ziziphus jujuba* extract (0.2%, 0.4%, and 0.6%) added to milk prior to starter culture inoculation on the structural, physicochemical, bioactive, volatile, and sensory properties of acid-curd cheese (tvarog). The experimental design included the determination of pH, titratable acidity, cheese yield, texture profile parameters, instrumental color, total polyphenol content, saponin content, antioxidant capacity, and volatile compound profile, along with semi-consumer sensory evaluation.
The addition of the extract did not significantly influence cheese yield, final pH, or titratable acidity ($P \geq 0.05$). However, significant differences were observed in textural parameters ($P < 0.05$). Increasing extract concentration resulted in higher hardness and adhesiveness, accompanied by reduced springiness and cohesiveness, indicating the formation of a denser and less elastic protein matrix, likely due to interactions between phenolic compounds and the casein matrix. Also, instrumental color was significantly affected ($P < 0.05$) by treatment. Lightness (L*) decreased, whereas redness (a*) and yellowness (b*) increased with increasing extract concentration, resulting in higher chroma (C*) values and a shift in hue angle toward warmer cream-to-light brown tones. These changes may be attributed both to the intrinsic pigmentation of the extract and to altered light-scattering properties within the curd microstructure.
Total polyphenol and saponin contents increased in the experimental groups and were accompanied by enhanced antioxidant capacity ($P < 0.05$). Despite these compositional changes, the volatile compound profile showed only slight variations relative to the control, indicating minimal alterations in aroma-forming pathways. Semi-consumer evaluation revealed overall acceptable sensory quality; however, product acceptance was dependent on extract concentration. These findings indicate that the extract modulated protein–polyphenol interactions within the casein gel network, affecting the structural organization of the dairy colloidal system. A moderate supplementation level maintained acceptability comparable to the control sample, whereas the highest concentration (0.6%) resulted in a noticeable decline in sensory quality, particularly in texture-related attributes and overall perception.

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Glycoproteins as modulators of yogurt colloidal structure and aroma during refrigerated storage

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Lactoferrin is a bioactive iron-binding glycoprotein naturally present in mammalian milk, which has attracted increasing attention as a functional ingredient in food systems. This protein exhibits numerous biological activities, including antimicrobial, antiviral, anti-inflammatory, and antioxidant effects, making it valuable for the development of functional dairy products. Due to these biological properties, lactoferrin is increasingly used as a nutraceutical ingredient in food products, including dairy matrices, to enhance their nutritional and health-promoting value. In fermented dairy products such as yogurt, the addition of lactoferrin may also influence physicochemical properties, microbial stability, and structural characteristics during storage [1,2,3]. Therefore, incorporating lactoferrin into dairy systems is of considerable interest both from a technological perspective and for the development of innovative functional foods with improved quality and health benefits [4].
The aim of the present study was to evaluate the effect of bovine lactoferrin (Lactoferrin MIG-95 SD AGG; Mercurius Production GmbH, Germany) added to milk at three concentrations (0.8, 1.0, and 1.2 g L^{-1}) on yogurt quality parameters and volatile compound profile during refrigerated storage.
Physicochemical properties, including pH, titratable acidity, syneresis, and color parameters, were determined. Rheological analysis was performed to investigate potential modifications in gel structure. Furthermore, antioxidant activity and volatile compound profiles were analyzed. The analyses were conducted on the 1st, 7th, 14th, and 21st days of refrigerated storage. Product acceptability was evaluated using a semi-consumer sensory assessment.
The addition of lactoferrin significantly influenced yogurt color parameters ($P < 0.05$). The lowest pH values were observed in samples containing the highest lactoferrin concentration (1.2 g L^{-1}). A gradual decrease in pH was observed in all samples during storage, which corresponded with an increase in titratable acidity. The presence of lactoferrin significantly reduced the degree of syneresis compared with the control samples. Volatile compound analysis revealed differences in the aroma profile depending the duration of refrigerated storage. Rheological measurements indicated that the addition of lactoferrin influenced the structural characteristics of the yogurt gel. Semi-consumer panel showed that the yogurts were generally well accepted, although the level of acceptance varied with the amount of lactoferrin added to fermented product.
Research financed by the Ministry of Science and Higher Education of Poland as part of the targeted subsidy " *Research network of natural science universities for the development of the Polish dairy sector - research project* " (SUP-RIM) (MEiN/2023/DPI/2866).

Keywords:
lactoferrin; yogurt; rheological properties; volatile compounds; syneresis

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Corchorus olitorius L. extract attenuates dexamethasone-induced muscle atrophy by modulating proteostasis and mitochondrial quality control

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Sarcopenia is rapidly emerging as a critical global health concern in the era of population aging. This progressive age-related skeletal muscle disorder is characterized by an imbalance between protein synthesis and degradation, accompanied by mitochondrial dysregulation. In the absence of approved pharmacological therapies, natural bioactive compounds have emerged as promising multi-target alternatives. The role of *Corchorus olitorius* L., generally called molokhia, in regulating skeletal muscle protein metabolism remains largely unexplored despite its various biological activities. This study aimed to evaluate the protective efficacy of *Corchorus olitorius* L. extract (COE) against dexamethasone (Dex)-induced muscle atrophy in C2C12 myotubes. Phytochemical analysis revealed substantial total phenolic and flavonoid contents with marked antioxidant capacity, providing a biochemical basis for its muscle-protective effects. COE downregulated Dex-induced expression of atrophy-related factors including myostatin as well as KLF15, MuRF1 and MAFbx. Moreover, COE alleviated Dex-induced impairment of mitochondrial quality control, as evidenced by the sustained expression of mitochondrial biogenesis markers (LKB1, SIRT1, PGC-1α and Tfam) and fusion regulators (Mitofusin 2 and OPA1). Additionally, COE restored mitochondrial function, further supported by the recovery of mitochondrial membrane potential ($\Delta\Psi_m$). Taken together, these results suggest that COE mitigates muscle atrophy by restoring protein homeostasis and maintaining mitochondrial integrity, supporting its potential as a functional food ingredient for muscle health.

Keywords:
Corchorus olitorius L., sarcopenia, skeletal muscle atrophy, protein synthesis and degradation, mitochondrial biogenesis, function and dynamics

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Acknowledgements:
This research was supported by Basic Science Research Program through the National Research Foundation of Korea (RS-2021-NR060125) funded by the Ministry of Education (2026).

Effect of Ziziphus jujuba extract on selected quality properties of yogurt during refrigerated storage

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Extracts from *Ziziphus jujuba* are recognized as rich sources of bioactive compounds, including polyphenols, flavonoids, triterpenoids, and saponins, which exhibit antioxidant, anti-inflammatory, antimicrobial, and functional properties [1–4]. Due to this diverse phytochemical profile, jujube has long been used as both a traditional medicinal fruit and a functional food ingredient, with growing scientific interest in its incorporation into value-added food products [2,4]. In recent years, increasing attention has been directed toward the application of plant-derived additives in dairy systems to enhance their functional value while modulating physicochemical, rheological, and sensory properties [5]. Previous studies have demonstrated that the addition of jujube pulp to yogurt can improve antioxidant activity and sensory acceptability while influencing textural attributes and water-holding capacity [6]. Moreover, jujube mucilage has been proposed as a natural stabilizer in stirred yogurt, contributing to modifications in viscosity, syneresis, and gel structure [7]. These findings highlight the technological and nutritional potential of jujube-derived ingredients in fermented dairy products.

The aim of the present study was to evaluate the effect of jujube extract addition (0.2%, 0.4%, and 0.6%) on the physicochemical, rheological, volatile, bioactive, and sensory properties of yogurt during 21 days of refrigerated storage. The analyses included pH, titratable acidity, syneresis, and color parameters. Rheological properties were determined to assess gel structure modifications. Total polyphenol content, saponin content, and antioxidant capacity were evaluated, and volatile compound profiles were characterized. Additionally, a semi-consumer sensory evaluation was conducted to assess product acceptability.

The results demonstrated that the addition of jujube extract significantly affected the analyzed parameters ($P < 0.05$). In the initial stage, yogurts supplemented with the extract exhibited higher pH and lower titratable acidity compared with the control, suggesting a temporary delay in acidification. However, during storage, enhanced post-acidification was observed, particularly at higher extract concentrations. Syneresis exhibited a biphasic pattern: higher extract levels initially increased whey separation, whereas prolonged storage led to structural stabilization and reduced syneresis relative to the control. The extract significantly decreased lightness (L*) and increased redness (a*) and yellowness (b*), resulting in higher color saturation (C*) and a shift toward warmer hues, with high color stability during storage. Furthermore, the addition of jujube extract significantly increased ($P < 0.05$) total polyphenol and saponin contents, as well as antioxidant capacity compared with the control group. Rheological analysis confirmed modifications in yogurt gel structure, and volatile compound profiling revealed qualitative and quantitative changes associated with extract addition. Semi-consumer evaluation indicated acceptable sensory quality, depending on the extract concentration.

The observed changes suggest that the extract influenced intermolecular interactions within the yogurt gel matrix, thereby modifying the structural integrity and colloidal stability of the system during storage. Overall, the findings indicate that *Ziziphus jujuba* extract may serve as a promising functional ingredient in yogurt production.

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Granada, 22 - 26 March 2026
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